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TITLE

SOLID STATE IMAGE PICKUP APPARATUS

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This application is a continuation-in-part of (1)  
Application Serial No. 314,275, filed February 23, 1989,  
which is a continuation of Application Serial No. 929,892,  
filed November 13, 1986, now abandoned; and (2)  
Application Serial No. 460,012, filed January 2, 1990,  
which is a continuation of Application Serial No. 096,534,  
filed September 14, 1987, now U.S. Patent No. 4,914,519,  
issued April 3, 1990.

BACKGROUND OF THE INVENTION

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Field of the Invention

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The present invention relates to a solid state image  
pickup apparatus and, more particularly, to a solid state  
image pickup apparatus having a plurality of photoelectric  
transducer elements each having a capacitor electrode on a  
control electrode region of a corresponding semiconductor  
transistor.

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The present invention also relates to a solid state image  
pickup apparatus for selectively reading out a plurality  
of sensor signals and, more particularly, to a solid state  
image pickup apparatus capable of eliminating unnecessary  
components such as variations in dark signals and drive  
noise.

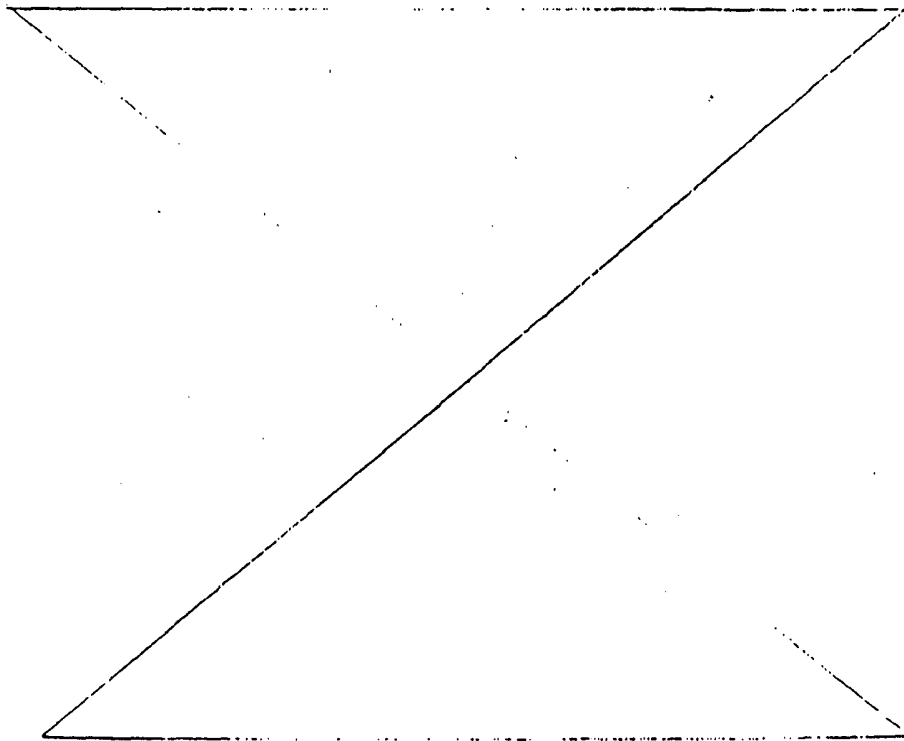
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Related Background Art

A TV or SV camera with an image sensor such as a CCD or MOS sensor has an aperture mechanism. Photoelectric transducer apparatuses each having a TV or SV camera with an automatic aperture mechanism are described in Japanese Patent Disclosure (Kokai) Nos. 12759/1985 to 12765/1985.

This photoelectric transducer apparatus includes a photosensor having a plurality of sensor cells each having a capacitor formed on a control electrode of a corresponding semiconductor transistor.

In the conventional photoelectric transducer apparatus described above, noise is often mixed in an output signal read out from the photosensor cells due to variations in dark voltage generated in the cells within arbitrary store time.



An output signal corresponding to the dark current component generated within the photosensor cell is prestored as reference optical information in an external memory in a conventional apparatus. A reference output signal derived from the reference optical information and an output signal from the actual optical information read out from the photosensor cell are compared with each other, and the output signal of the actual optical information is corrected, thereby eliminating the noise component caused by the dark voltage.

In the conventional photoelectric transducer apparatus described above, in order to constitute a photoelectric transducer system, the resultant system is undesirably complicated since a separate external circuit including a noise removal memory is required.

When a conventional photoelectric transducer apparatus is applied to a video camera or the like, the following problem occurs. When photoelectric transducer cells are arranged in a two-dimensional matrix and scanned in the vertical and horizontal directions, holes are stored in the base of each photoelectric transducer cell in a store mode upon reception of strong light. The base potential is forward-biased with respect to the emitter potential. The potential of a vertical line connected to the emitter electrode of each photoelectric transducer

cell receiving strong light is increased to cause a blooming phenomenon. In order to prevent this, it is proposed that the vertical lines are grounded for a period excluding the readout operation, thereby refreshing the charge overflowed onto the vertical line. However, the vertical line can be grounded for only the horizontal blanking period, i.e., about 10  $\mu$ s. Therefore, the charge overflowed onto the vertical line during the horizontal scanning period still causes the blooming phenomenon.

In the readout mode, when made signals are sequentially output by horizontal scanning after they are stored in a vertical line, a dummy signal is generated during the store of the signal in the vertical line. In other words, a smear phenomenon occurs.

In addition, the period for performing the refresh operation in the conventional apparatus is about 10  $\mu$ s in the horizontal blanking period. The refresh time is short to result in incomplete refreshing and hence an after image phenomenon.

Furthermore, assume that when the conventional photoelectric transducer apparatus is used as a single-plate type solid-state imaging device in a color television video camera, color filters are deposited or adhered onto the pixels. If an alignment scheme such as a Bayer alignment is used to form vertical

lines in units of colors, i.e., R, G, and B, at least two vertical lines are required for the pixels of each column. In this case, since the vertical line portion does not serve as the photosensitive portion, the light-receiving area is reduced by the two vertical lines for each column. In other words, the opening of the aperture is undesirably reduced.

In a conventional photosensitive transducer apparatus, negative and positive voltages are required to bias an output amplifier, and the constitution is thus complicated. It is difficult to read out the signal component without degrading the frequency characteristics.

Fig. 15A is a schematic circuit diagram of a conventional solid-state image pickup apparatus.

Referring to Fig. 15A, signals from sensors S1 to Sn are respectively amplified by amplifiers A1 and An, and transistors T1 to Tn are sequentially turned on. A dot sequential output appears on an output line 101A. The dot sequential signal is amplified by a buffer amplifier 102A, and the resultant signal appears as an output signal Vout.

In the conventional image pickup apparatus described above, variations in input/output characteristics of the amplifiers A1 to An are included in the sensor signals as the dot sequential output appearing on the output line 101A. As a result, steady pattern noise undesirably occurs.

Fig. 15B shows a schematic arrangement of another conventional photoelectric transducer apparatus.

Referring to Fig. 15B, signals read out from photosensors S1 to Sn are temporarily stored in storage capacitors C1 to Cn. Transistors T1 to Tn are sequentially turned on at timings of a scanning circuit SH, and the readout signals sequentially appear on an output line 101A and are output to an external device through an amplifier 102A.

In the above photoelectric transducer apparatus, however, unnecessary components such as dark signals and drive noise of the photosensors are undesirably included.

Drive noise is defined as noise generated when a photosensor is driven to read out a signal. The drive noise components are noise caused by manufacture variations such as element shapes and smear caused by element-isolation and depending on radiation amounts.

The dark signal is defined as a dark current of a photosensor and greatly depends on accumulation time and temperature of the photosensor.

This drive noise will be described in detail. Variations in drive capacity of a drive element for driving a photoelectric transducer element and variations in capacity of a photoelectric transducer

1 element cause variations in leakage component of  
drive pulses. These variation components as an infor-  
mation signal are superposed on a necessary photo-  
electric transducer signal and are read out. The  
5 cause of generation of drive noise will be de-  
scribed below.

Fig. 15C is a schematic view of a photo-  
electric transducer element described in Japanese  
Patent Laid-Open Gazette No. 12764/1985, Fig. 15D is a  
10 timing chart of drive pulses for driving the photo-  
electric transducer element shown in Fig. 15C, and  
Fig. 15E is a chart showing the base potential of the  
photoelectric transducer element.

Referring to Fig. 15C, the photoelectric  
15 transducer element includes a base accumulation type  
bipolar transistor B, a drive capacitor  $C_{ox}$  for  
reverse- or forward-biasing the transistor B in  
response to a drive pulse  $\phi_r$ , and a refresh transistor  
 $Q_r$ . The transistor B has junction capacitances  $C_{bc}$   
20 and  $C_{be}$ . It should be noted that  $C_{ox}$ ,  $C_{bc}$ , and  $C_{be}$   
are referred to as capacitances or capacitors  
hereinafter, as needed. The capacitances  $C_{ox}$ ,  $C_{bc}$ ,  
and  $C_{be}$  are added to obtain a charge storage  
capacitance  $C_{tot}$ .

25 The operation of the photoelectric transducer  
element will be described below.

Assume that the initial value of a base

potential  $V_B$  is given as  $V_0$ . When the drive pulse  $\phi_r$  is set at a potential  $V_{gr}$  at time  $t_1$ , a voltage  $V_a$  is applied to the base of the transistor B through the drive capacitor  $C_{ox}$ . In this case, the voltage  $V_a$  can be represented as follows:

$$\begin{aligned} V_a &= C_{ox} / (C_{ox} + C_{bc} + C_{be}) \times V_{gr} \\ &= (C_{ox} / C_{tot}) \times V_{gr} \quad \dots (1) \end{aligned}$$

When the drive pulse  $\phi_{rh}$  is set at a high potential at time  $t_2$ , a transistor  $Q_r$  is turned on.

When the transistor B is forward-biased, the base potential  $V_B$  is abruptly decreased. A time interval  $T_C$  between time  $t_2$  and time  $t_3$  is a so-called refresh time interval.

The drive pulse  $\phi_r$  is set at zero at time  $t_3$ , and a voltage  $-V_a$  is added to the base voltage  $V_B$ , so that the base voltage  $V_B$  is set at  $V_2$ . This reverse-biased state is the accumulation state.

The above description was confined to one photoelectric transducer element. However, a line or area sensor has a large number of photoelectric transducer elements. The capacitances of the capacitors  $C_{ox}$ ,  $C_{bc}$ , and  $C_{be}$  between a large number of photoelectric transducer elements vary by a few fractions of 1%. For example, if the following conditions are given:

$C_{ox} = C_{bc} = C_{be} \approx 0.014 \text{ pF}$ , and  $V_{gr} = 5 \text{ V}$  and the capacitance variation is 0.2 %, then a



1 variation  $\Delta V_a$  in capacitance division voltage  $V_a$  is  
about 3 mV.

The variation  $\Delta V_a$  can be reduced by refreshing.  
However, when the refresh mode is changed to an  
5 accumulation operation mode (time  $t_3$ ), the variation  
occurs again to produce  $\Delta V_b$ . The variation  $\Delta V_b$  does  
not satisfy relation  $\Delta V_b = -\Delta V_a$ , and the correlation  
cannot be established therebetween according to test  
results.

10 The above fact is assumed to be derived from  
different bias voltage dependencies of  $C_{bc}$  and  $C_{be}$ .

In the next read cycle, when the transistor B  
is forward-biased, the variation in base potential  
thereof is approximated as follows:

15 
$$\Delta V^2 = \Delta V_a^2 + \Delta V_b^2 + 2K\Delta V_a\Delta b \quad \dots (2)$$

for  $K$  is -1 or more. As a result, the variation  $\Delta V$   
becomes steady drive noise of about 4 to 5 mV.

The variation in leakage component of such a  
drive pulse (to be referred to as drive noise  
20 hereinafter) is eliminated according to the following  
conventional technique. That is, the above drive noise  
is stored in a memory means and is read out and  
subtracted from the signal read out from the sensor to  
obtain a true information signal.

25 The conventional drive noise correction  
technique described above causes a bulky, expensive  
photoelectric transducer element which does not have

any industrial advantage.

In particular, in case of that the numbers of elements arranged in the horizontal direction and vertical direction are five hundred respectively, an area sensor requires 250,000 photoelectric elements arranged in a matrix form. In addition, when the resolution of the sensor is also taken into consideration, a memory of several megabits is required.

The unnecessary signals such as drive noise and a dark signal pose serious problems when an image of a dark object is to be picked up, i.e., image pickup at a low intensity. In the low-intensity image pickup mode, an information signal level is low and accordingly the S/N ratio is degraded. As a result, image quality is degraded. In order to improve image quality, the unnecessary signals must be reduced.

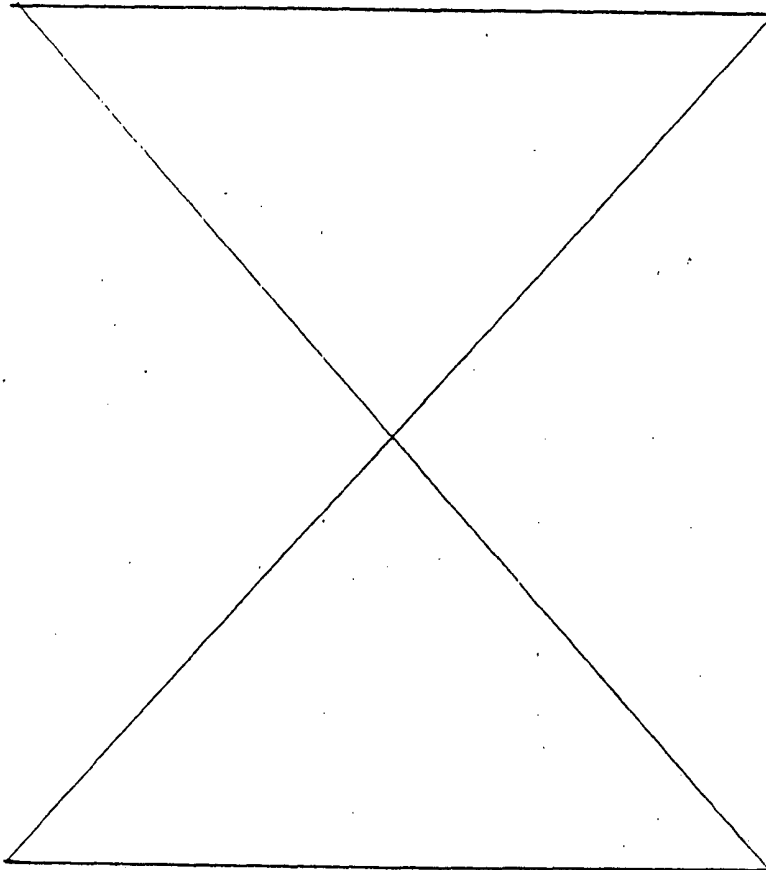
As described above, however, the dark signal primarily depends on temperature and charge accumulation time, although the drive noise rarely depends thereon. If these unnecessary signals are to be eliminated, the dark signal must be separated from the drive noise and a correction coefficient must be determined, thus requiring a large-capacity memory. As a result, signal processing is complicated and expensive, and an image pickup apparatus is undesirably bulky.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a photoelectric transducer apparatus capable of solving the conventional drawbacks described above.

It is another object of the present invention to provide a simple photoelectric transducer apparatus capable of eliminating variations in dark voltage.

It is still another object of the present invention to provide a photoelectric transducer apparatus comprising optical information storing means for storing optical information (light or bright signals) read out from a photoelectric transducer element and dark voltage storing means for storing a voltage corresponding to



a dark voltage component read out from the photoelectric transducer element, wherein actual optical information stored in the optical information storing means is simultaneously read out together with the dark voltage component stored in the dark voltage storing means onto separate output lines, thereby correcting the information corresponding to the dark voltage in units of optical sensor cells and hence removing noise caused by variations in dark voltage from the output signal from the photosensor cells.

In order to achieve the above object, according to an aspect of the present invention, there is provided a photoelectric transducer apparatus having a plurality of photoelectric transducer elements each having a capacitor electrode formed on a control electrode of a corresponding semiconductor transistor, the apparatus being adapted to sequentially select each element in units of lines, to control a potential of the control electrode of the selected photoelectric transducer element through the capacitor electrode, to store carriers in the control electrode region, and to read out a signal component corresponding to the amount of charge stored in the control electrode region, comprising: optical information storing means for storing optical information read out from the photoelectric transducer element; and dark voltage storing means for storing a voltage

corresponding to a dark voltage read out from the photoelectric transducer element, wherein actual optical information stored in the optical information storing means and information corresponding to the dark voltage component stored in the dark voltage storing means are simultaneously read out onto different information output lines.

The information corresponding to the dark voltage component stored in the dark voltage storing means is read out onto the information output line therefor, and at the same time the information corresponding to the dark voltage is corrected in units of photosensor cells, thereby eliminating noise caused by variations in dark voltage.

The noise corresponding to the dark voltage component can, therefore, be processed within the sensor. An external circuit or the like need not be used to easily constitute a system configuration, thereby obtaining a low-cost photoelectric transducer apparatus.

It is still another object of the present invention to provide an imaging element and an apparatus using the same, wherein the after image, blooming, and smearing can be prevented with a simple construction.

It is still another object of the present invention to provide a color imaging element having

a large aperture.

In order to achieve these objects, according to another aspect of the present invention, there is provided a photoelectric transducer apparatus comprising:

- a plurality of photoelectric transducer cells;
- a signal read line for reading out signals from the plurality of photoelectric transducer elements; and
- a plurality of capacitors for selectively storing the signals read out through the signal read line.

According to this aspect of the present invention, since the plurality of capacitors for selectively storing the signals read out through the signal read line are provided, the image signal appearing on the vertical line can be shortened, thereby reducing the frequency of occurrence of the blooming and smearing phenomena. Since the capacitor can be disconnected from the pixel after the image signal is stored in the capacitor, the refresh time can be prolonged to reduce the occurrence of the after image phenomenon. In addition, if the photoelectric transducer apparatus is used in a color video camera, the number of capacitors can be that of the color signals of the row pixels, and only one vertical line is used, thereby increasing the aperture.

It is still another object of the present

1 invention to provide a photoelectric transducer  
apparatus wherein a single power source can be used  
without degrading the signal component of the read  
signal.

5 In order to achieve the above object, according  
to still another aspect of the present invention,  
there is provided a photoelectric transducer apparatus  
for reading output a read signal from a photoelectric  
transducer element through an amplifier after the  
10 read signal is temporarily stored in a storing means,  
comprising switching means for properly applying a  
bias voltage to the storing means.

With the above arrangement, the reference  
potential of the store capacitor can be properly  
15 changed to use a single power source without degrading  
the signal component of the read signal.

It is still another object of the present  
invention to provide a photoelectric transducer  
apparatus little subjected to smearing or blooming.

20 In order to achieve the above object, according  
to still another aspect of the present invention, a  
capacitor is arranged in a vertical signal line  
through a switch to store the signal from the photo-  
electric transducer cell in the capacitor, thereby  
25 resetting the vertical signal line, so that the  
signal component in the capacitor is free from  
smearing or blooming.

5           It is another object of the present invention to eliminate variations in drive noise in units of sensor cells.

          It is still another object of the present invention to compensate for variations in electrical  
10       characteristics of a plurality of amplifiers arranged for sensor cells.

          In order to achieve the above objects according to an aspect of the present invention, there is provided a solid state image pickup apparatus  
15       having a selector for selecting a plurality of sensor signals through corresponding amplifiers, comprising a processing circuit for calculating a difference between a selected sensor signal and a reference signal selected through the same circuit  
20       for selecting the sensor signal.

          The sensor signal selected by the selector, therefore, includes a noise component caused by variations in amplifier characteristics since the sensor signal is amplified by the corresponding  
25       amplifier. For this reason, the reference signal is selected through the same amplifier which has amplified the sensor signal, so that the amplifier



noise is superposed on the reference signal. A difference between the selected sensor signal and the selected reference signal is calculated to eliminate the noise component.

5       According to another aspect of the present invention, there is provided a photoelectric transducer apparatus having storage means for storing a signal from a photoelectric transducer element, wherein the storage means comprises first  
10       storage means for storing the signal read out from the photoelectric transducer element and second storage means for storing a residual signal after the photoelectric transducer element is refreshed, and further  
15       comprising difference processing means for calculating a difference between the readout and residual signals respectively stored in the first and second storage means.

      Since the residual signal obtained upon completion of refreshing is subtracted from the  
20       readout signal, the unnecessary components such as a dark signal and drive noise of the photoelectric transducer element can be eliminated.

      A MOS, electrostatic induction, or base accumulation type photosensor may be used as a  
25       photoelectric transducer element.

      "Refreshing" of the photoelectric transducer element means erasure of optical information of the

1 photoelectric transducer element. In some photo-  
sensors, optical information is erased simultaneously  
when the information is read out. However, in some  
photosensors, optical information is kept unerased  
5 even after the information is read out.

According to still another aspect of the  
present invention, in order to eliminate the con-  
ventional drawbacks described above, there is provided  
a solid state image pickup apparatus comprising a,  
10 plurality of photoelectric transducer elements, first  
storage means, arranged in units of photoelectric  
transducer elements, for storing a video signal, second  
storage means, arranged in units of photoelectric  
transducer elements, for storing noise components,  
15 first readout means for simultaneously and independent-  
ly reading out signals for photoelectric transducer  
elements of a plurality of horizontal lines from the  
first storage means, and second readout means for  
adding signals for the photoelectric transducer  
20 elements of the plurality of horizontal lines from  
the second storage means and for reading out a sum  
signal.

With the above arrangement, it is assumed  
that the drive noise is generated as a sum of noise  
25 components generated in the refresh, charge accumu-  
lation, and readout modes of the photoelectric  
transducer element and the drive noise level is

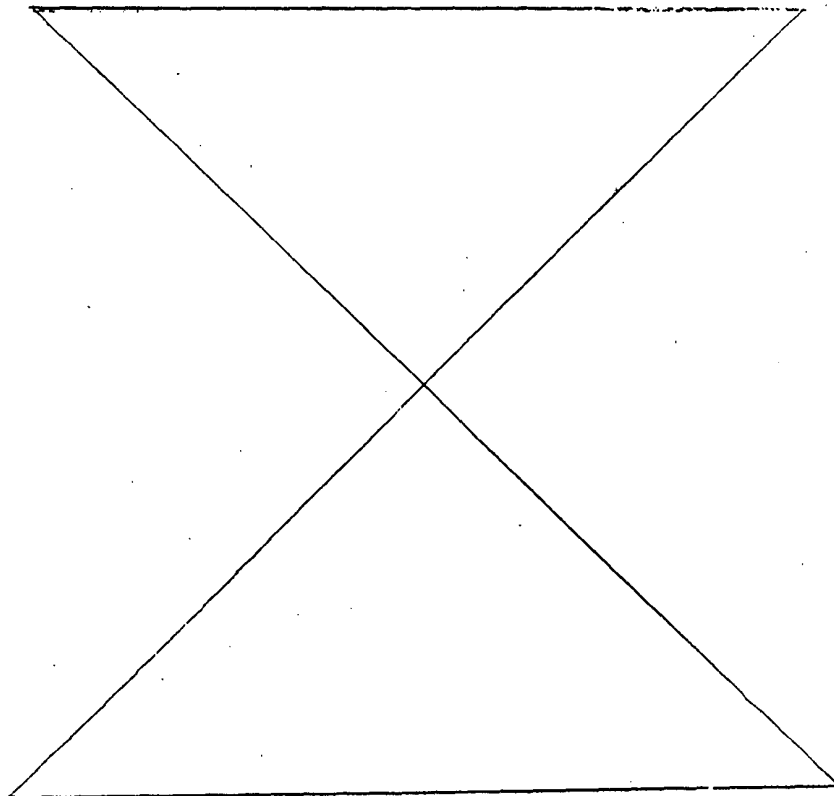
substantially identical in each mode. A difference between the photoelectric transducer signal read out upon completion of exposure and drive noise read out in the photoelectric transducer signal readout mode is calculated to eliminate the drive noise. It should be noted that the noise components are read out after they are added, thereby reducing the number of read lines.

According to still another aspect of the present invention, in order to eliminate the conventional drawbacks described above, there is provided a solid state image pickup apparatus comprising photoelectric transducer elements, a plurality of storage capacitors for storing readout signals when the photoelectric transducer elements are read-accessed a plurality of times, dot sequential processing means for converting signals from the storage capacitors into a dot sequential signal, and clamping means for clamping some components of the dot sequential signal from the dot sequential processing means.

With the above arrangement, it is assumed that the drive noise is generated as a sum of noise components generated in the refresh, charge accumulation, and readout modes of the photoelectric transducer element and the drive noise level is substantially identical in each mode. The photo-

1 electric transducer signal read out upon completion  
of exposure and drive noise read out in the photo-  
electric transducer signal readout mode are converted  
into a dot sequential signal, and the drive noise  
5 component is clamped, thereby eliminating the drive  
noise included in the photoelectric transducer  
signal components.

The above and other objects, features, and  
advantages of the present invention will be apparent  
10 from the following detailed description in conjunction  
with the accompanying drawings.



BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram of a photoelectric transducer apparatus according to a first embodiment of the present invention;

Fig. 2 is a timing chart for explaining the operation of the apparatus in Fig. 1;

Fig. 3A is a circuit diagram of a photoelectric transducer apparatus according to a second embodiment of the present invention;

Fig. 3B is a circuit diagram showing the main part of a third embodiment;

Fig. 4 is a timing chart for explaining the operation of the second and third embodiments of the present invention;

Fig. 5 is a circuit diagram of a photoelectric transducer apparatus according to a fourth embodiment of the present invention;

Fig. 6 is a timing chart for explaining the operation of the apparatus in Fig. 5;

Fig. 7 is a circuit diagram of a photoelectric transducer apparatus according to a fifth embodiment of the present invention;

Fig. 8 is a timing chart for explaining the operation of the apparatus in Fig. 7;

Fig. 9 is a circuit diagram of a photoelectric transducer apparatus according to a sixth embodiment of the present invention;

Fig. 10 is a circuit diagram of a photoelectric transducer apparatus according to a seventh embodiment of the present invention;

Fig. 11 is a timing chart for explaining the apparatus in Fig. 10;

Fig. 12 A is a circuit diagram for explaining a basic operation of the seventh embodiment of the present invention;

Fig. 12 B is a timing chart showing the voltage waveforms in the seventh embodiment;

Fig. 13 is a block diagram of an imaging device on the basis of the above embodiments of the present invention; and

Fig. 14 is a circuit diagram showing part of an eighth embodiment of the present invention.

Fig. 15A is a schematic circuit diagram of a conventional solid state image pickup apparatus;

Fig. 15B is a schematic view of another conventional solid state image pickup apparatus;

Figs. 15C to 15E are views for explaining the principle of generation of drive noise of a photoelectric transducer element;

Figs. 16A and 16B are schematic circuit diagrams showing a solid state image pickup apparatus according to an embodiment of the present invention;

Fig. 17 is a circuit diagram showing an arrangement of switches SW1 to SWn in the apparatus of Fig. 16A;

Fig. 18 is a circuit diagram showing another

arrangement of switches SW1 to SWn in the apparatus of Fig. 16A;

Fig. 19A is a circuit diagram showing another arrangement of a difference processing circuit in the apparatus of Fig. 16A;

Fig. 19B is a timing chart for explaining the operation of the difference processing circuit shown in Fig. 19A;

Fig. 20A is a schematic circuit diagram showing a solid state image pickup apparatus according to another embodiment of the present invention;

Fig. 20B is a timing chart for explaining the operation of the apparatus shown in Fig. 20A;

Fig. 21 is a block diagram showing an image pickup system using the apparatus (of any embodiment of Figs. 15-20 described above) as an image pickup device;

Fig. 22A is a schematic sectional view of a photoelectric transducer cell described in Japanese Patent Laid-Open Gazettes Nos. 12759/1985 to 12765/1985.

Fig. 22B is an equivalent circuit diagram thereof;

Fig. 23 is a graph showing the relationship between a width  $t_r$  of a refresh pulse applied to the photoelectric transducer cell and a photoelectric transducer cell output after refreshing;

Fig. 24 is a circuit diagram for explaining

1 a basic arrangement of a solid state image pickup  
apparatus according to still another embodiment of  
the present invention;

5 Fig. 25 is a timing chart for explaining the  
operation of the apparatus shown in Fig. 24;

Fig. 26 is a circuit diagram showing the  
overall arrangement of the apparatus shown in Fig. 24;

Figs. 27A and 27B are timing charts for explain-  
ing two operation modes of the apparatus shown in

10 Fig. 24;

Fig. 28 is a circuit diagram of a solid state  
image pickup apparatus according to still another  
embodiment of the present invention;

15 Fig. 29 is a detailed circuit diagram of a  
readout circuit R<sub>i</sub> in the apparatus shown in Fig. 28;

Fig. 30 is a timing chart for explaining the  
operation of the apparatus shown in Fig. 28;

Fig. 31 is a block diagram showing an image  
pickup system using the apparatus (Fig. 24) as an  
20 image pickup device;

Fig. 32 is a circuit diagram showing an image  
pickup apparatus according to still another em-  
bodiment of the present invention;

Fig. 33 is a block diagram showing an image  
pickup system using the image pickup apparatus (Fig.  
25 32) as an area sensor;

Fig. 34 is a circuit diagram of a solid state



image pickup apparatus according to still another embodiment of the present invention;

Fig. 35 is a timing chart for explaining the operation of the apparatus shown in Fig. 34;

Fig. 36 is a schematic view showing an arrangement when the apparatus in Fig. 34 is applied to an area sensor; and

Fig. 37 is a timing chart for explaining the operation of the area sensor shown in Fig. 36.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a circuit diagram of a photoelectric transducer apparatus as a line sensor according to a first embodiment of the present invention, and Fig. 2 is a timing chart for explaining the operation thereof.

Referring to Figs. 1 and 2, capacitor electrodes 101 of photosensor cells 100 are commonly connected to a driving line, and collector electrodes 102 thereof are commonly connected to a positive voltage terminal.

A driving terminal is connected to the driving

line.

A pulse signal is applied to the driving terminal to drive the photosensor cells 100. Emitter terminals 103 of the photosensor cells 100 are connected to vertical signal lines and commonly connected to each other through reset FETs 104. The emitter terminals 103 are connected to a ground terminal GND.

The gate electrodes of the FETs 104 are commonly connected to a first reset terminal.

The FETs 104 are switching field effect transistors.

The vertical signal lines are connected to store capacitors 106 through FETs 105 and to the source electrodes of FETs 107. The drain electrodes of the FETs 107 are commonly connected to a horizontal signal line. The gate electrodes of the FETs 105 are commonly connected to a control terminal.

The gate electrodes of the FETs 107 are respectively connected to output terminals of a scanning circuit 108.

Horizontal signal lines are connected to an external output terminal through an output amplifier 109 and to the ground terminal GND through an FET 100.

The gate terminal of the FET 110 is connected to a second reset terminal.

The FET 110 is a field effect transistor for resetting the horizontal line.

The operation of the circuit in Fig. 1 will be described with reference to a timing chart in Fig. 2.

The control and first reset terminals are simultaneously set at H level during the reset time. During the reset time, the optical information stored in the store capacitors 106 is discharged through the FETs 104.

When the control terminal is set at H level and the first reset terminal is set at L level, the optical information stored in the photosensor cells 100 is read out onto the vertical signal lines by applying the readout pulse signal to the driving terminal. Therefore, the optical information is stored in the store capacitors 106.

In this manner, when the readout pulse signal is set at H level, readout operation of the photosensor cells 100 is started. After the lapse of a predetermined period of time, the readout pulse signal is set at L level, thereby terminating the readout operation.

When the control terminal is set at L level, and the first reset and driving terminals are set at H level, the refresh operation state is obtained. The optical information stored in the photosensor cells 100 is erased through the FETs 104.

When the refresh pulse signal is set at L

level, the refresh operation is ended.

Thereafter, during the period until the readout operation state is obtained again, the store time for storing the carriers in the photosensor cells 100 is defined.

The signal pulses from the output terminals of the scanning circuit 108 are used to sequentially turn on the FETs 107 according to the shift timings.

The optical information signals stored in the store capacitors 106 are sequentially read out onto the horizontal lines by horizontal scanning of the scanning circuit 108. The readout signals are amplified by the output amplifier 109 and appear at the external output terminal.

When all optical information signals stored in the store capacitors 106 are read out completely, the reset time is initialized again.

The above operations are thus repeated.

With the above arrangement, the signal charge is not kept on the vertical signal line for a long period of time, thus reducing blooming and smearing.

A second embodiment of the present invention will be described with reference to the accompanying drawings.

Fig. 3 is a circuit diagram of a photoelectric transducer apparatus according to the second embodiment.

Referring to Fig. 3, photosensor cells 1 as the photoelectric transducer elements are one-dimensionally arranged.

Capacitor electrodes 2 of the photosensor cells 1 are commonly connected to a driving line and to a driving terminal. Collector electrodes 3 of the photosensor cells 1 are commonly connected to a positive voltage terminal.

Emitter electrodes 4 of the photosensor cells 1 are respectively connected to vertical lines 5. The vertical lines 5 are commonly connected through FETs 6. The FETs 6 are connected to a ground terminal 7.

The gate electrodes of the FETs 6 are commonly connected to a first reset terminal.

The capacitors 9 and the source electrodes of the FETs 10 are respectively connected to the vertical lines 5 through FETs 8. The capacitors 9 are connected to a ground terminal 12 through a ground line 11.

The capacitors 9 are signal charge store capacitors, respectively.

The gate electrodes of the FETs 10 are respectively connected to output terminals 14 of the scanning circuit 13. The drain electrodes of the FETs 10 are connected to an output amplifier 16 through a horizontal line 15. The output terminal of the output amplifier 16 is connected to an external

output terminal 17, so that an output voltage is extracted from the external output terminal 17.

The gate electrodes of the FETs 10 are respectively connected to the gate electrodes of FETs 18. The drain electrodes of the FETs 18 are connected to an output amplifier 20 through an output line 19.

The output terminal of the output amplifier 20 is connected to an external output terminal 21, so that an output voltage is extracted from the external output terminal 21.

The source electrodes of the FETs 18 are connected to the vertical lines 5 through FETs 22.

In the above embodiment, one electrode of each of capacitors 24 is connected between a corresponding one of the source electrodes of the FETs 18 and a corresponding one of the FETs 22 through a corresponding one of vertical lines 23. The other electrode of each of the capacitors 24 is connected to the ground line 11.

The capacitors 24 serve as dark voltage store capacitors, respectively. Reset FETs 26 are connected between the lines 15 and 19 and ground, respectively. The gate electrodes of the FETs 26 are connected to the second reset terminal. A control circuit 27 supplies timing pulses (Fig. 4) to the respective terminals.

The operation of the above embodiment will be described below.

As shown in the timing chart of Fig. 4, the photosensor cells store optical information corresponding to the amounts of light upon light store operation during the light irradiation store time.

During a predetermined period of time until the light information readout, the photosensor cells 1 perform store operations of carriers upon light irradiation. During the reset time, both the control and first reset terminals are set at H level, so that the charges stored in the capacitors 9 are reset through the corresponding FETs 6.

The control terminal is set at H level, and the first reset terminal is set at L level. When a readout pulse voltage is applied to the driving terminal, the optical or light information stored in the photosensor cells 1 is read out onto the vertical lines, and the light information is stored in the capacitors 9.

When the light information readout time has elapsed, the first reset terminal is set at H level and the control terminal is set at L level. In this state, when the refresh pulse voltage is applied to the driving terminal, the photosensor cells 1 are maintained in the refresh state. The light information stored in the photosensor cells 1 is erased

through the FETs 6.

When the refresh time has elapsed, the photosensor cells 1 are temporarily shielded from light so that a shading time is started.

In this case, the photosensor cells 1 store the dark voltage generated in the dark state. It should be noted that the dark voltage store time is controlled to be equal to the light irradiation store time.

Subsequently, both the dark voltage readout terminal and the first reset terminal are set at H level to reset through the FETs 6 the charges stored in the capacitors 24 during the reset time.

The light information corresponding to the dark voltage components, stored in the photosensor cells 1 is read out onto the vertical lines under the following conditions. The dark voltage readout terminal is set at H level, the first reset terminal is set at L level, and the readout pulse voltage  $E_r$  is applied to the driving terminal. Therefore, the dark voltage signals are stored in the corresponding capacitors 24.

When the dark voltage readout time has elapsed, the dark voltage readout terminal is set at L level, and the first reset terminal is set at H level. The refresh pulse voltage  $E_0$  is applied to the driving terminal to set the photosensor cells 1 in the refresh state.



When a predetermined period of time has elapsed, the refresh pulse voltage applied to the driving terminal is set at L level. Therefore, the refresh time is terminated. Along with this, the shading time is ended, and the first reset terminal is set at L level.

Subsequently, clocks are supplied to the scanning circuit 13 to sequentially shift the output pulses from the output terminals 14 thereof. The FETs 10 and 18 are sequentially turned on in response to these timing pulses.

By this horizontal scanning, light information signals are sequentially read out from the capacitors 9 onto the horizontal line 15. In synchronism with the readout operation, the information signals corresponding to the dark voltage components stored in the capacitors 24 are read out onto the output line 19.

In this manner, the light information signals read out onto the horizontal line 15 are output to the external output terminal 17 through the output amplifier 16. The information signals corresponding to the dark voltage components read out onto the output line 19 are output to the external output terminal 21 through the output amplifier 20, so that the output voltage is thus extracted from this external output terminal.

For example, the readout operation for one

horizontal scanning time is completed, and the reset time is started. Thereafter, the above operations will be repeated.

Since the photoelectric transducer apparatus of this embodiment is operated as described above, an additional external circuit which was required in the conventional photoelectric transducer apparatus to remove the noise component caused by the dark voltage need not be used, thereby simplifying the system configuration. Therefore, demand for a low-cost photoelectric transducer apparatus can be satisfied.

In the above embodiment, the actual light information signals simultaneously read out onto the corresponding lines and the information signals corresponding to the dark voltage components are amplified by the output amplifiers 16 and 20 in an output circuit 25, and the amplified signals are extracted through the external output terminals, respectively. However, the present invention is not limited to the above arrangement. As shown in Fig. 3, (a third embodiment), the output circuit 25 may be replaced with a differential amplifier 28 to subtract the information corresponding to the dark voltage components from the actual light information. Light information representing a difference may be output from a terminal 29.

In the second and third embodiments, the dark voltage store time is set to be equal to the light irradiation time. However, such setting need not be performed.

5 For example, by effectively utilizing the relationship between the dark voltage store time and the amount of dark voltage components generated by the photosensor cells 1, i.e., a substantially proportional relationship, the dark voltage store time  
10 may be set to be shorter than the light irradiation time, and gains of the output amplifiers 16 and 20 in the output circuit 25 may be independently controlled. Alternatively, the capacitances of the store capacitors 9 and 24 are adjusted to obtain the  
15 same effect as in the above embodiments.

In the second and third embodiments, the photosensor cells are one-dimensionally aligned. However, the arrangement of the cells is not limited to this.

20 As described above, the photoelectric transducer apparatus comprises light information storing means for storing light information read out from the photoelectric transducer element, and dark voltage storing means for storing a voltage corresponding to the dark voltage component read out from  
25 the photoelectric transducer element. The actual light information stored in the light information

storing means and the information corresponding to the dark voltage component stored in the dark voltage storing means are simultaneously read out from the separate output lines. Therefore, the information corresponding to the dark voltage included in the output can be corrected in units of photosensor cells when the actual optical information read out from the photosensor cell is output, and noise caused by variations in dark voltage can be removed from the output signal. Unlike in the conventional photoelectric transducer apparatus, an additional external circuit is not required to simplify the system configuration. In addition, demand for an economical photoelectric transducer apparatus can be satisfied.

A fourth embodiment of the present invention will be described in detail with reference to the accompanying drawings.

Fig. 5 is a circuit diagram of photoelectric transducer elements arranged in a 4 x 4 matrix to constitute a photoelectric transducer apparatus.

The photoelectric transducer apparatus includes: basic photosensor cells 100 (the collector of each bipolar transistor is connected to the substrate and the substrate electrode), horizontal lines 31, 31', 31'', and 31''' serving as the readout-refresh pulse lines; a vertical shift register 32 for generating a readout pulse; buffer MOS transistors

33, 33', 33", and 33'" arranged between the vertical  
shift register 32 and the horizontal lines 31, 31',  
31", 31'" ; a terminal 34 for applying a pulse  $\phi_R$  to  
the drains of the buffer MOS transistors 33, 33', 33",  
5 and 33'" ; a vertical shift register 32' for generating  
a refresh pulse; buffer MOS transistors, 47, 47', 47",  
and 47'" formed between the vertical shift register  
32' and the horizontal lines 31, 31', 31", and 31'" ;  
a terminal 48 for applying a pulse to the drains of  
10 the buffer MOS transistors 47, 47', 47", and 47'" ;  
vertical lines 35, 35', 35", and 35'" serving as  
vertical readout lines for reading out signal charges  
from the basic photosensor cells 100; capacitors  
37-1, 37-2, 37-1', 37-2', 37-1", 37-2", 37-1'",  
15 and 37-2'" for storing these signal charges;  
transfer MOS transistors 36-1, 36-2, 36-1', 36-2',  
36-1", 36-2", 36-1'", and 36-2'" arranged between  
the vertical lines 35, 35', 35", and 35'" and the  
capacitors 37-1, 37-2, 37-1', 37-2', 37-1", 37-2",  
20 37-1'", and 37-2'" ; a horizontal shift register  
46 for generating a pulse for selecting each store  
capacitor; gate MOS transistors 38-1, 38-2, 38-1',  
38-2', 38-1", 38-2", 38-1'", and 38-2'" for charging/  
discharging the store capacitors 37-1, 37-2, 37-1',  
25 37-2', 37-1", 37-2", 37-1'", and 37-2'" ; output  
lines 39-1 and 39-2 for reading out the store voltages  
and supplying them to an amplifier; MOS transistors

40-1 and 40-2 for refreshing the charges on the readout  
lines; a terminal 41 for applying the refresh pulse  
to the MOS transistors 40-1 and 40-2; transistors  
42-1 and 42-2 such as bipolar transistors, MOSFETs  
or JFETs for amplifying the output signals; output  
terminals 43-1 and 43-2 of the transistors 42-1 and  
42-2; MOS transistors 44, 44', 44", and 44'" for  
refreshing the charges stored on the vertical lines  
35, 35', 35", and 35'" ; a terminal 45 for supplying  
a pulse to the gates of the MOS transistors 44, 44',  
44", and 44'" ; a horizontal shift register 46 for  
turning on the MOS transistors 38-1, 38-2, 38-1',  
38-2', 38-1", 38-2", 38-1'", and 38-2'" ; and a  
control circuit 200 for supplying signals to the  
respective terminals.

The operation of the photoelectric transducer  
apparatus will be described with reference to Fig. 5  
and a timing chart of Fig. 6.

Assume that the collector potential of the  
photosensor cells is kept at a positive potential  
in the following description.

The store operation is performed until the  
tl, and holes corresponding to the amounts of light  
incident on the photoelectric transducer cells 100  
are respectively stored in their p-type base regions.

At time tl, a pulse signal  $\phi_{vc}$  rises to turn  
on the transistors 44, 44', 44", and 44'" . A pulse

1 signal  $\phi T1$  rises to turn on the transistors 36-1,  
36-1', 36-1", and 36-1''' to refresh the store capacitors  
37-1, 37-1', 37-1", and 37-1'''. A pulse signal  $\phi Hc$   
rises to turn on the transistors 40-1 and 40-2 to  
5 refresh the residual charges on the output lines  
39-1 and 39-2. Subsequently, the pulse signal  $\phi c$   
falls to turn off the transistors 44, 44', 44", and  
44''', and the vertical lines 35, 35', 35", and 35'''  
and the capacitors 37-1, 37-1', 37-1", and 37-1'''  
10 are set in the floating state. A pulse signal  $\phi v1$   
is output from the vertical shift register 32 to  
turn on the transistor 33. When a readout pulse  
signal  $\phi R$  is then applied to the terminal 34 and  
to the horizontal line 31 through the transistor  
15 33, the readout operation of the photoelectric  
transducer cells 100 of the first row is started.  
By this readout operation, the readout signals from  
the cells of the first row appear on the vertical  
lines 35, 35', 35", and 35''' and in the store  
20 capacitors 37-1, 37-1', 37-1", and 37-1'''. When  
the readout operation is completed, the pulse signal  
 $\phi T1$  falls to turn off the transistors 36-1, 36-1',  
36-1", and 36-1'''. The capacitors 37-1, 37-1',  
37-1", and 37-1''' and the vertical lines 35, 35',  
25 35", and 35''' are disconnected, and then the residual  
charges on the vertical lines 35, 35', 35", and 35'''  
are refreshed.

At time  $t_2$ , a pulse signal  $\phi T_2$  rises to turn on the transistors 36-2, 36-2', 36-2'', and 36-2''' so that the charges in the store capacitors 37-2, 37-2', 37-2'', and 37-2''' are refreshed. Subsequently, the pulse signal  $\phi v_c$  falls to turn off the transistors 44, 44', 44'', and 44'''. A pulse signal  $\phi v_2$  is output from the vertical shift register 33', and the readout pulse signal  $\phi R$  is supplied to the horizontal line 31' through the terminal 34. In this state, the readout operation of the photoelectric transducer cells 100 of the second row is started. By this readout operation, the readout signals from the cells 100 of the second row appear on the vertical lines 35, 35', 35'', and 35''' and in the store capacitors 37-2, 37-2', 37-2'', and 37-2'''. Upon completion of the readout operation for the second row, the pulse signal  $T_2$  falls to turn off the transistors 36-2, 36-2', 36-2'', and 36-2''', and the capacitors 37-2, 37-2', 37-2'', and 37-2''' and the lines 35, 35', 35'', and 35''' are disconnected. The pulse signal  $\phi v_c$  rises to refresh the residual charges from the vertical lines 35, 35', 35'', and 35'''.

At time  $t_3$ , the pulse signal  $\phi H_c$  falls to turn off the transistors 40-1 and 40-2. The pulse signal  $\phi H_1$  is output from the horizontal shift register 46 to turn on the transistors 38-1 and 38-2. The charges in the capacitors 37-1 and 37-2



are amplified by the transistors 42-1 and 42-2 through the transistors 38-1 and 38-2 and the output lines 39-1 and 39-2. The amplified signals appear at the terminals 43-1 and 43-2. When this output operation is completed, the pulse signal  $\phi_{Hc}$  rises to refresh the output lines 39-1 and 39-2. Subsequently, the pulse signals  $\phi_{H2}$  and  $\phi_{H3}$  are sequentially output from the horizontal shift register 46. In the same manner as described above, the readout signals from the cell of the first row and the second column and the cell of the second row and the second column and the readout signals from the cell of the first row and the third column and the cell of the second row and the third column are sequentially output from the terminals 43-1 and 43-2. Every time the readout signals appear, the output lines 39-1 and 39-2 are refreshed.

At time  $t_4$ , a pulse signal  $\phi_{c1}$  is output from the vertical shift register 32' to turn on the transistors 47 and 47'. A pulse signal  $\phi_F$  is applied to the terminal 48 so that the refresh pulse is applied to the horizontal lines 31 and 31' through the transistors 31 and 31'. As a result, the refresh operation of the photoelectric transducer cells 100 of the first and second rows is performed.

The readout and refresh operations for the cells 100 of the third and fourth rows are performed at time  $t_5$  in the same manner as in the cells of the first and second rows. The readout and refresh operations are repeated for the cells 100 of the first and second rows at time  $t_6$ . The above operations are repeated.

In the above operation, the time required for sending the readout signal onto the vertical line is the period between rising of the pulse signal  $\phi_R$  and falling of the pulse signal  $\phi_{T1}$ , i.e., between the times  $t_1$  and  $t_2$  when the output from the photoelectric transducer cell 100 of the first row and the first column is assumed. This time interval apparently has a large margin. In the conventional photoelectric transducer apparatus applied in the video camera, the vertical line selected last by horizontal scanning stores the signal charge for about 52.5  $\mu s$ . For example, if the time interval between rising of the pulse signal  $\phi_R$  and falling of the pulse signal  $\phi_{T1}$  is set to be 0.5  $\mu s$ , the apparatus of this embodiment can be improved by about 105 times (40 dB) for blooming and smearing, as compared with the conventional apparatus.

Since the store capacitors are arranged, the photosensitive transducer cells are disconnected from the store capacitors by turning off the transistors 36-1, 36-2, 36-1', 36-2', 36-1'', 36-2''.

36-1'", and 36-2'" after the signal charges are stored  
in the store capacitors, the photoelectric transducer  
cells 100 can be sufficiently refreshed. For example,  
the refresh time may be a time interval between times  
5 t3 and t5, i.e., one horizontal scanning cycle.  
Therefore, the after image phenomenon can be reduced  
as compared with the conventional case.

If the photoelectric transducer apparatus is  
applied to a color video camera and color filters are  
10 formed on the sensor cells, the number of capacitors  
is that of the colors of column cells, and the operation  
as described above is performed. In this case,  
only one vertical line is used for each column, and  
the aperture of the sensor cells is not reduced.  
15 For example, as shown in Fig. 5, the color filters  
R, G, and B are arranged according to the Bayer's  
scheme, and the cells are operated at the timings  
shown in Fig. 6. B signals are stored in the  
capacitors 37-1 and 37-1', G signals are stored in  
20 the capacitors 37-2, 37-1', 37-2", and 37-1'", and  
R signals are stored in the capacitors 37-2' and  
37-2'", respectively.

In the above embodiment, the two vertical  
lines are simultaneously accessed. However, the  
25 number of lines is not limited to two, but can be  
extended to three or more. In this case, the number  
of store capacitors is that of vertical pixels which

are simultaneously accessed.

Fig. 7 is a circuit diagram showing a fifth embodiment of the present invention. A decoder 49 is arranged between a vertical shift register 32 and horizontal lines 31, 31', 31", and 31''', and a control circuit 200 is operated at timings shown in Fig. 8.

In this embodiment, the decoder 49 also serves the function of the photoelectric transducer cell refresh vertical register 46 of the fourth embodiment (Fig. 5), thereby further simplifying the system configuration.

The operation of the fifth embodiment will be described with reference to the timing chart of Fig. 8. Assume that the store operation is performed until time  $t_1$ , and that the holes corresponding to the amounts of light incident on the photoelectric transducer cells 100 are respectively stored in their p-type base regions.

At time  $t_1$ , a pulse signal  $\phi_{vc}$  has already risen, the vertical lines have already been grounded, and a pulse signal  $\phi_{T1}$  rises to refresh the charges of the capacitors 37-1, 37-1', 37-1", and 37-1'''. Thereafter, when the pulse signal  $\phi_{vc}$  falls to set the vertical lines and the capacitors in the floating state, the decoder 49 outputs a pulse  $\phi_{D1}$ .

The signals from the photoelectric transducer cells 100 of the first row appear on the vertical

lines and in the capacitors 37-1, 37-1', 37-1", and  
37-1'''. After the readout operation is completed,  
the pulse signal  $\phi T1$  falls to disconnect the capacitors  
37-1, 37-1', 37-1", and 37-1''' from the vertical lines,  
5 and the pulse signal  $\phi vc$  rises again to refresh the  
vertical lines. The pulse signal  $\phi T2$  rises to refresh  
the capacitors 37-2, 37-2', 37-2", and 37-2''', and  
the pulse signal  $\phi vc$  then falls. When the pulse  
signal  $\phi D2$  rises again, the signals from the photo-  
10 electric transducer cells of the second row appear  
on the vertical lines and the capacitors 37-2, 37-2',  
37-2", and 37-2'''. Thereafter, the pulse signal  $\phi T2$   
falls and the pulse signal  $\phi vc$  rises to refresh the  
vertical lines. In this state, the signals from the  
15 first row are stored in the capacitors 37-1, 37-1',  
37-1", and 37-1''', and the signals from the second  
row are stored in the capacitors 37-2, 37-2', 37-2",  
and 37-2'''.

In the same manner as in the first embodiment,  
20 these stored signals are sequentially read out from  
time  $t3$  to time  $t5$ . In this case, during the time  
interval from time  $t4$  to time immediately before  
time  $t5$ , the pulse signals  $\phi D1$  and  $\phi D2$  are set at  
high level, so that the photoelectric transducer  
25 cells 100 of the first and second rows are refreshed.

The readout and refresh operations of the  
photoelectric transducer cells of the third and

fourth rows are performed in the same manner as described above.

According to this embodiment, the refresh and readout operations of the photoelectric transducer cells of each cell are performed by using a single vertical shift register, thereby simplifying the system configuration.

In the above embodiment, the two output lines are used. However, the number of output lines may be three or more. For example, as shown in a sixth embodiment of Fig. 9, four output lines are used in units of colors of filters. In this case, the load of the output lines can be reduced into 1/2 of the two output lines. In addition, an image processing circuit can also be simplified.

The arrangement of Fig. 9 is different from that of Fig. 5 in the following points. Output lines 39-3 and 39-4 are added. Transistors 38-1 and 38-1' are connected to a transistor 39-3 instead of the transistor 39-1. Transistors 38-2' and 38-2'' are connected to a transistor 39-4 instead of the transistor 39-2. Transistors 40-3 and 40-4, the gates of which are commonly connected to the gates of transistors 40-1 and 40-2, are added to refresh the output lines 39-3 and 39-4. A transistor 42-3 for outputting a signal from the output signal 39-3, an output terminal 43-4, a transistor 42-4 for

outputting a signal from the output line 39-4, and  
an output terminal 43-4 are added.

Other arrangements of Fig. 9 are the same as  
those of Fig. 5, and the same reference numerals as  
in Fig. 5 denote the same parts in Fig. 9.

In the photoelectric transducer apparatuses  
in the fourth to sixth embodiments as described above  
in detail, a plurality of capacitors are arranged for  
each readout line of the photoelectric transducer  
cells. The signal charges can be stored in the  
capacitors in a short period of time, and then the  
readout lines can be disconnected therefrom. Therefore,  
blooming and smearing caused by the presence of the  
signal charges on the readout lines can be completely  
prevented.

Furthermore, since the refresh time can be  
sufficiently prolonged, the after image phenomenon  
can be effectively prevented.

Many lines are often simultaneously accessed  
when the photoelectric transducer apparatus is applied  
to a color video camera or the like. The capacitors  
corresponding to the pixels to be accessed are arranged  
for each readout line. The number of readout lines  
need not be increased, and thus the aperture can be  
increased.

A seventh embodiment of the present invention  
will be described below.

Fig. 10 is a circuit diagram of a photoelectric transducer apparatus according to the seventh embodiment of the present invention.

Referring to Fig. 10, a driving pulse  $\phi R$  is applied from a control circuit 200 to capacitor electrodes of photoelectric transducer cells  $S1$  to  $S_n$ . A predetermined positive voltage is applied to the collector electrodes of the cells  $S1$  to  $S_n$ . The emitter electrodes of the cells  $S1$  to  $S_n$  are respectively connected to vertical lines  $VL1$  to  $VL_n$ . Each of these vertical lines is connected to one terminal of a corresponding one of store capacitors  $C1$  to  $C_n$  (each having a capacitance  $C_t$ ) through a corresponding one of transistors  $Qt1$  to  $Qt_n$ . The other terminal of each of the capacitors  $C1$  to  $C_n$  properly receives a bias voltage  $V_{ct}$  in a manner to be described later.

One terminal of each of the capacitors  $C1$  to  $C_n$  is connected to an output line 201 through a corresponding one of transistors  $QS1$  and  $QSn$ . The output line 201 has a stray capacitance  $C_h$  equal to the capacitance  $C_t$  of each of the store capacitors  $C1$  to  $C_n$ .

The input terminal of an output amplifier 202 is connected to the output line 201 and to a transistor  $Q_{rh}$  for properly applying a reset voltage  $V_{rh}$ . The value of the reset voltage  $V_{rh}$  is selected within the



range wherein the linearity of the output amplifier 202 is not degraded. In this embodiment, the range is 1.5 to 3.5 V. The output amplifier 202 is connected to a single power source and is driven thereby.

Pulses  $\phi_{h1}$  to  $\phi_{hn}$  are sequentially applied from a scanning circuit 103 to the gate electrodes of the transistors  $Q_{S1}$  and  $Q_{Sn}$ . A pulse  $\phi_t$  is applied to the gate electrodes of the transistors  $Q_{t1}$  to  $Q_{tn}$ .

A voltage  $V_{vc}$  is applied to the respective vertical lines through transistors  $Q_{r1}$  to  $Q_{rn}$ . The gate electrodes of these transistors receive a pulse  $\phi_{vc}$ . A control circuit 200 supplies a driving pulse of each terminal. Fig. 11 is a timing chart for explaining the operation of the control circuit.

The transistors  $Q_{r1}$  to  $Q_{rn}$  and the transistors  $Q_{t1}$  to  $Q_{tn}$  are turned on in response to the pulses  $\phi_{vc}$  and  $\phi_t$ , respectively, to clear (duration  $T_1$ ) the capacitors  $C_1$  to  $C_n$ . Subsequently, the pulse  $\phi_{vc}$  is set at L level, and the capacitors  $C_1$  to  $C_n$  are charged (duration  $T_2$ ) with the readout signals from the photo-electric transducer cells in response to the driving pulse  $\phi_r$ . In this case, the bias voltage  $V_{ct}$  is the ground potential.

After the bias voltage  $V_{ct}$  is set to be +2V, the signals from the capacitors  $C_1$  to  $C_n$  are output at timings of the shift pulses  $\phi_{h1}$  to  $\phi_{hn}$ .

More specifically, the transistor  $Q_{S1}$  is

turned on in response to the pulse  $\phi_{h1}$ . As described above, the signal read out from the photoelectric transducer cell S1 and stored in the capacitor C1 is read out onto the output line 201. Subsequently, the transistor Qrh is turned on in response to the pulse  $\phi_{rh}$ , and the output line 201 is reset to the reset voltage Vrh (e.g., +2V). In the same manner as described above, the readout signals stored in the capacitors C2 to Cn are sequentially read out onto the output line 101 and are output through the output amplifier 102 (a duration T3).

When the output operation is completed, the refresh operation is performed in response to the pulse  $\phi_{vc}$  and the driving pulse  $\phi_r$  (a duration T4).

The basic operation of the circuit in Fig. 10 will be described below.

Fig. 12 A is a circuit diagram for explaining the basic operation of the circuit in Fig. 10, and Fig. 12 B is a timing chart showing the voltage waveforms.

Referring to Fig. 12 A, a switch for selecting the ground voltage (contact A) or the bias voltage of +2V (contact B) is equivalently connected to the store capacitor Ct. A switch Qrh for applying the reset voltage Vrh (+2V) is equivalently connected to the output line 201. Also assume that the voltage of the capacitor Ct is  $v_1$ , and that the voltage of the

output line 201 is  $v_2$ .

The capacitor  $C_t$  is connected to the contact A and grounded, and the readout signal from the sensor is stored in the capacitor  $C_t$ . The capacitor  $C_t$  is then connected to the contact B and receives the bias voltage of +2V. The voltage of the capacitor  $C_t$  at the time of zero level of the readout signal is set to be equal to the reset voltage of the output line.

Subsequently, when the switch  $Q_s$  is closed, the  $1/2$  component of the signal of the voltage  $v_1$  appears on the output line 201 since  $C_t = C_h$ . This voltage is input as a voltage  $V_2$  to the output amplifier 202. Closing of the switch  $Q_{rh}$  causes resetting of the output line 201 at the voltage of +2V (Fig. 12 B ).

According to this embodiment, only the signal component is input to the output amplifier 102, and the input voltage does not greatly vary upon resetting. The dynamic range of the output amplifier 202 can therefore be increased. The amplitude of the voltage  $V_{rh}$  or  $V_{ct}$  can have a large margin.

By setting the potential of the output line 201 connected to the input terminal of the output amplifier 202 at a low potential excluding the ground potential, the  $V_{ss}$  terminal of the output amplifier 202 can be grounded and a positive voltage (+5V in this case) can be applied to the  $V_{dd}$  terminal thereof

by a single power source. (For example, if the reset potential is zero, the negative and positive potentials are respectively applied to the Vss and Vdd terminals, and thus two power sources are required).

5        If the bias voltage of the capacitor Ct is not changed, the potential of the output line 201 greatly varies between the reset potential Vrh and the signal component potential of the readout signal. The sensor signal is normally amplified to a proper  
10    signal level by a signal processor (to be described later). If the above unnecessary component is generated, the circuit system is saturated since the unnecessary component has a magnitude larger than that of the signal component, thereby degrading  
15    the signal component. However, according to the above embodiment, the above problem does not occur. If an output amplifier having a wide dynamic range is arranged, it prevents use of a low-level driving source and design of a compact imaging device.  
20    However, according this embodiment, the wide dynamic range of the amplifier 202 is not required, so that a compact imaging device can be provided.

25        Now assume the charge/discharge time. A reset potential portion of the output signal Vout can sufficiently drive a load capacitance (a bonding capacitance, a wiring capacitance, an input transistor capacitance, and the like) by a source current

of a source follower circuit. However, the signal component portion of the output signal becomes a sink current of the source follower circuit. If an output resistance is not sufficiently small, a discharge time constant is increased to degrade linearity of a small signal. A decrease in output resistance causes current consumption loss. According to this embodiment, since the dynamic range of the output amplifier can be narrowed, this problem does not occur.

In order to eliminate the unnecessary voltage variation component, a sample/hold (S/H) circuit is required. The relationship between a timing pulse for the S/H circuit and the signal component is very important. It is desirable not to arrange the S/H circuit to obtain good temperature characteristics and the power source voltage characteristics. However, if the S/H circuit is not arranged, the blocking characteristic curve of a low-pass filter becomes steep when the output signal is band-limited thereby, and hence image quality is degraded. However, according to this embodiment, since the S/H circuit need not be used, the apparatus of this embodiment can be stably operated against temperature and voltage variations.

Fig. 13 shows a schematic arrangement of an imaging device using the above embodiment.

Referring to Fig. 13, an imaging element 501

has the same arrangement as in the embodiment of Fig. 10. An output signal  $V_{out}$  from the imaging element 501 is gain-controlled by a signal processing circuit 502 and is output as a standard NTSC signal or the like.

Various pulses  $\phi$  and the bias voltage  $V_{ct}$  for driving the imaging element 501 are generated by a control circuit 200. The control circuit 200 is operated under the control of the control unit 504. In this case, the control circuit 200 also serves as the switching means for properly applying the bias voltage  $V_{ct}$ . The control unit 504 controls the gain or the like of the signal processing circuit 502 on the basis of the output from the imaging element 501 to control the amount of light incident on the imaging element 501.

The bias voltage  $V_{ct}$  applied to the store capacitors  $C_1$  to  $C_n$  is supplied from the control circuit 200. However, an internal power source 601 shown in Fig. 14, may be arranged. In this case, the internal power source 601 is operated in response to a control pulse  $\phi_{ct}$  from the control unit 504 to generate the bias voltage  $V_{ct}$ .

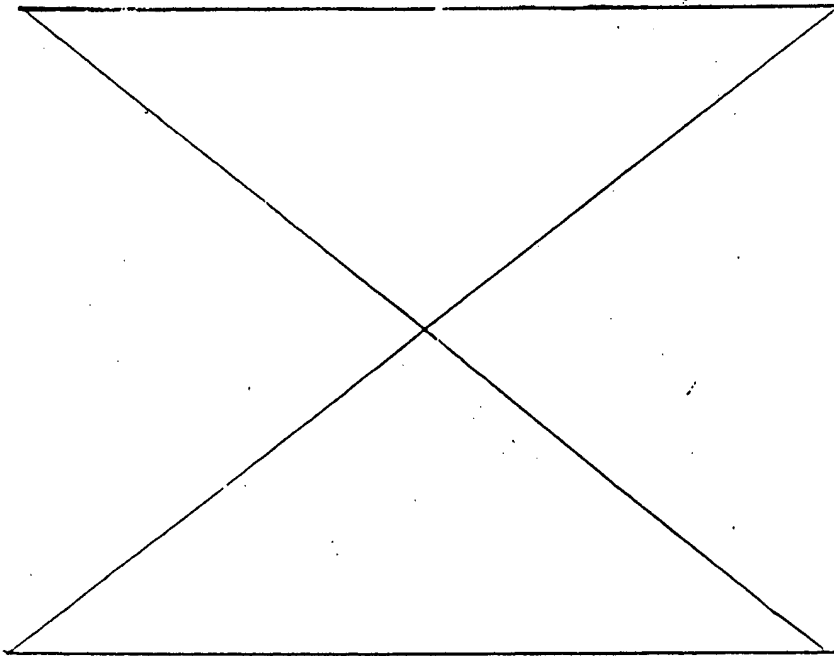
In the photoelectric transducer apparatus as described in detail, a simple method of temporarily changing the reference potential of the capacitors in the readout mode is employed, so that only a

single power source for the imaging driving voltage can be used. As a result, the imaging device can be made more compact at lower power consumption.

Fig. 16A is a schematic circuit diagram of a solid state image pickup apparatus according to an embodiment of the present invention.

Referring to Fig. 16A, switches SW1 to SWn are arranged to select corresponding inputs in response to pulses  $\phi c1$  to  $\phi cn$ . The switches SW1 to SWn respectively receive sensor signals S1 to Sn from photosensors S1 to Sn arranged in a line or a matrix form. The switches SW1 to SWn also receive signals E from reference signal sources E, respectively.

The output terminals of the switches SW1 to SWn are respectively connected to the input terminals



of amplifiers A1 to An. The output terminals of the amplifiers A1 to An are connected to an output line 101A through corresponding transistors T1 to Tn.

Pulses  $\phi_1$  to  $\phi_n$  from a scanning circuit SH such as a shift register are respectively supplied to the gate electrodes of the transistors T1 to Tn. The transistors T1 to Tn are turned on in response to the pulses  $\phi_1$  to  $\phi_n$ .

The output line 101A is grounded through a transistor 103A. A pulse  $\phi_{hrs}$  is applied to the gate electrode of the transistor 103A. The output line 101A is also connected to a difference processing circuit 1A. An output signal Vout free from noise components is output from the difference processing circuit 1A.

In the difference processing circuit 1A in this embodiment, the output line 101A is connected to an amplifier 11A. The input terminals of sample/hold (S/H) circuits 12A and 13A are connected to the output terminal of the amplifier 11A. Pulses  $\phi_{h1}$  and  $\phi_{h2}$  as control signals are respectively supplied to the S/H circuits 12A and 13A so that the S/H circuits 12A and 13A hold the inputs at the input timings of these pulses, respectively. The output terminals of the S/H circuits 12A and 13A are respectively connected to the noninverting and inverting input terminals of a differential amplifier 14A. The output signal Vout is output from the differential amplifier 14A.



The operation of this embodiment will be described below.

When the reference E is input to the amplifier A1 upon operation of the switch SW1, the reference signal E is amplified by the amplifier A1, and an amplified signal E1' is output to the transistor T1. In this case, only the transistor T1 is kept on in response to the pulse  $\phi_1$ , and other transistors T2 to Tn are kept off. The reference signal E1' is selected by the transistor T1 and appears on the output line 101A. The reference signal E1' is held in the S/H circuit 12A through the amplifier 11A. More specifically, the pulse  $\phi_1$  is supplied to the S/H circuit 12A when it holds the reference signal E1'.

The reference signal E1' held by the S/H circuit 12A is a signal reflecting variation characteristics of the amplifier A1, i.e., a signal including a noise component N1 which becomes a steady pattern noise. In other words,  $E1' = E + N1$ .

Subsequently, the transistor 103A is turned on in response to the pulse  $\phi_{hrs}$  to remove the charge left on the output line 101A. An output signal from the sensor S1 is input to the amplifier A1 through the switch SW1. In the same manner as described above, a sensor signal S1' amplified by the amplifier A1 appears on the output line 101A through the ON tran-

1     sistor T1 and is held by the S/H circuit 13 through  
the amplifier 11A.

      The sensor signal  $S1'$  held by the S/H circuit  
13A also reflects variation characteristics, i.e., a  
5     signal including the noise component  $N1$  ( $S1' = S1 + N1$ ).

      When the reference signal  $E1'$  and the sensor  
signal  $S1'$  are respectively held by the S/H circuits  
12A and 13A, the signals  $S1'$  and  $E1'$  are input to the  
10    differential amplifier 14A. The output  $Vout$  from the  
differential amplifier 14A is a difference ( $S1' - E1'$ )  
between the sensor and reference signals  $S1'$  and  $E1'$ ,  
thereby obtaining a signal ( $S1 - E$ ) free from the  
noise component  $N1$ . In this case, the reference signal  
15     $E$  represents the reference level of the sensor signal  
 $S1$ , so that  $E = 0$  is established. Therefore, the  
output signal  $Vout$  is the sensor signal  $S1$  before  
being subjected to the influence of the amplifier A1.

      When the sensor signal  $S1$  is output in this  
20    manner, the residual charge on the output line 101A  
is eliminated by the transistor 103A. At the timings  
in the same manner as described above, the sensor  
signals  $S2$  to  $Sn$  free from the noise components  $N2$   
to  $Nn$  are sequentially output from the differential  
25    amplifier 14A.

      In the above description, the reference  
signal  $E$  is read out prior to the corresponding sensor

signal. However, each sensor signal may be read out prior to the reference signal E.

In the above description, the reference and sensor signals  $E_1'$  and  $S_1'$  are held in the separate S/H circuits, respectively. However, one of the S/H circuits may be omitted, and the output terminal of the amplifier 11A may be directly connected to the amplifier 14A (Fig. 16B). In this case, one readout signal is held by the S/H circuit 12A in response to the pulse  $\phi_{h1}$ , and the output signal  $V_{out}$  is output from the differential amplifier 14A at the read timing of the other readout signal.

Fig. 17 is a circuit diagram showing an arrangement of switches  $SW_1$  to  $SW_n$  in the apparatus shown in Fig. 16A.

Referring to Fig. 17, a transistor 201A is turned on in response to a pulse  $\phi_t$  to store the sensor signal  $S_1$  in a capacitor  $C_1$ . Subsequently, a transistor 203A is turned on in response to a pulse  $\phi_{cb}$  to output the reference signal E to the amplifier A1.

When the reference signal  $E_1'$  is held as described above, the transistor 202A is turned on in response to a pulse  $\phi_{ca}$  to output the sensor signal  $S_1$  from the capacitor  $C_1$  to the amplifier A1.

The switches  $SW_2$  to  $SW_n$  have the same arrangement as that of the switch  $SW_1$ , and operations

of the switches SW2 to SWn are also the same as that of the switch SW1.

Fig. 18 is a circuit diagram showing another arrangement of the switches SW1 to SWn in the apparatus of Fig. 16A.

In this arrangement, the reference signal E is generated by drive noise caused by variations in leakage component of the sensor.

Referring to Fig. 18, a transistor 301A is turned on in response to a pulse  $\phi t1$  to store the sensor signal S1 in a capacitor C11. Subsequently, a transistor 303A is turned on in response to a pulse  $\phi t2$ . A sensor signal representing absence of optical information or the dark state thereof serves as the reference signal E. This reference signal E is stored in a capacitor C12. In this state, a drive noise component of the corresponding sensor is stored in the capacitor C12. In the same manner as described above, a transistor 304A is turned on to output the reference signal E from the capacitor C12 to an amplifier A1 and then a transistor 302A is turned on to output the sensor signal S1 from the capacitor C11 to the amplifier A1.

By using the sensor drive noise component as the reference signal E, the output  $V_{out} (= S1' - E1')$  from the differential amplifier 14A is free from the sensor drive noise component as well as the noise

component N1 of the amplifier A1.

Fig. 19A is a circuit diagram showing another arrangement of the difference processing circuit in the apparatus shown in Fig. 16A, and Fig. 19B is a timing chart for explaining the operation thereof.

Difference processing is performed by a clamping circuit in this arrangement.

Referring to Figs. 19A and 19B, the reference signal E1' amplified by the amplifier A1 appears on the output line 101A and is input to a clamp circuit through an amplifier comprising transistors 15A and 16A. In this case, the clamp circuit comprises a capacitor 17A and a transistor 18A. Since the transistor 18A in the clamp circuit is kept on in response to a clamp pulse  $\phi_s$ , the level of the reference signal E1' is clamped as the reference level. As a result, the sensor signal S1' subsequently appearing on the output line 101A is amplified by an amplifier of transistors 19A and 20A using the reference signal E1' as a reference level. In the same manner as in Fig. 15, the output signal Vout obtained by removing the reference signal E1' from the sensor signal S1' is obtained. Similarly, the clamp pulse  $\phi_s$  is generated at a read timing of the reference signal E1', and the sensor signals S1 to Sn free from the noise components are sequentially output.

Fig. 20A is a schematic circuit diagram of a

solid state image pickup apparatus according to another embodiment of the present invention, and Fig.20B is a timing chart for explaining the operation thereof.

Referring to Fig.20A, sensors B1 to Bn (to be referred to as B hereinafter) are base accumulation type phototransistors. A base potential of each transistor is controlled through a capacitor, and the carriers excited upon incidence of light are accumulated in the base region of the transistor. The accumulated voltage is read out as a sensor signal, or the accumulated carriers are removed.

A read or refresh pulse  $\phi_r$  is applied to the capacitor electrodes of the sensors B. The emitter electrodes of the sensors B which are adapted to read out sensor signals S1 to Sn (to be referred to as S hereinafter) are grounded through transistors Qr1 to Qrn (to be referred to as Qr hereinafter), respectively. The emitter electrodes are connected to temporary storage capacitors C11 to Cn1 through transistors Qa1 to Qan (to be referred to as Qa hereinafter) and to temporary storage capacitors C12 to Cn2 through transistors Qc1 to Qcn (to be referred to as Qc hereinafter), respectively.

The capacitors C11 to Cn1 are connected to the gate electrodes of amplifiers A1 to An through transistors Qb1 to Qbn, respectively. The capacitors C12 to Cn2 are connected to the gate electrodes of

the amplifiers A1 to An through transistors Qd1 to Qdn, respectively.

A voltage Vcc is applied to the first terminals of the amplifiers A1 to An, and an output line 501A is commonly connected to the second input terminals thereof.

A pulse  $\phi_{a1}$  is applied to the gate electrodes of the transistors Qb1 to Qbn through transistors Qel to Qen. A pulse  $\phi_{b1}$  is applied to the gate electrodes of the transistors Qd1 to Qdn through transistors Qf1 to Qfn.

Pulses  $\phi_1$  to  $\phi_n$  from a scanning circuit SH are sequentially supplied to the gate electrodes of the transistors Qel to Qen, Qf1 to Qfn, and T1 to Tn, respectively.

A transistor 502A is connected to the output line 501A, and a voltage Vss is applied to the output line 501A through the transistor 502A. A signal S' amplified by each amplifier and appearing on the output line 501A is input to the difference processing circuit 1A, and difference processing as described above is performed. It should be noted that the difference processing circuit 1A in this embodiment is of a differential type using the S/H circuit shown in Fig. 16A.

The operation of the apparatus of this embodiment will be described with reference to Fig. 20B.

Assume that carriers corresponding to the intensity levels of the incident light are stored in the base regions of the sensors B, respectively.

For a time interval  $T_{m1}$ , the transistors  $Q_r$  are kept on in response to the pulse  $\phi_{rh}$ , and the emitter electrodes of the sensors B and the vertical lines are grounded. At the same time, the transistors  $Q_a$  and  $Q_c$  are turned on in response to the pulses  $\phi_{t1}$  and  $\phi_{t2}$  to clear the carriers from the capacitors  $C_{l1}$  to  $C_{n1}$  and  $C_{l2}$  to  $C_{n2}$ , respectively.

For a time interval  $T_{m2}$ , the transistors  $Q_a$  are kept on in response to the pulse  $\phi_{t1}$  to supply the read pulse  $\phi_r$  to the sensors B. Therefore, the sensor signals  $S$  from the sensors B are stored in the capacitors  $C_{l1}$  to  $C_{n1}$ , respectively. These sensor signals include the drive noise components of the corresponding sensors.

For a time interval  $T_{m3}$ , the transistors  $Q_r$  are kept on in response to the pulse  $\phi_{rh}$  to ground the emitters of the sensors B. The sensors B are refreshed in response to the refresh pulse  $\phi_r$ . Upon completion of refreshing, the transistors  $Q_{rh}$  are turned off, and the transistors  $Q_c$  are turned on in response to the pulse  $\phi_{t2}$ . During this period, the read pulse  $\phi_r$  is applied to read out the signals from the sensors B. Their drive noise components, i.e., the above-mentioned reference signals  $E_1$  to  $E_n$



are respectively stored in the capacitors C12 to Cn2. Thereafter, the pulse  $\phi_r$  falls to cause the sensors B to start charge accumulation.

The above operations are performed during a blanking period BLK, and the signals temporarily stored in the corresponding capacitors are sequentially read out onto the output line 501A.

The transistors T1, Qe1, and Qf1 are turned on in response to the pulse  $\phi_1$ . The voltage Vcc is applied to the amplifier A1, and the amplifier A1 is rendered operative (other amplifiers A2 to An are rendered inoperative). The pulse  $\phi_{a1}$  rises in synchronism with the pulse  $\phi_1$  and the transistor Qb1 is turned on through the ON transistor Qe1. The sensor signal S1 stored in the capacitor C11 is amplified by the amplifier A1, and the amplified signal appears on the output line 501A and is then held in an S/H circuit 12A in a difference processing circuit 1A.

Subsequently, the pulse  $\phi_{b1}$  rises and then the transistor Qd1 is turned on through the transistor Qf1. The reference signal E1 stored in the capacitor C12 is amplified by the amplifier A1, and the amplified signal appears on the output line 501A and then held by an S/H circuit 13A.

It can be assumed that a potential of an input to the amplifier A1 can be reset to a reference

potential for a period from the time when the sensor signal S1 is output from the capacitor C11 to the amplifier A1 and to the time when the reference signal E1 is output from the capacitor C12.

However, most of the input capacitance of the amplifier A1 is an overlap capacitance of the transistors. The input capacitance is sufficiently smaller than the capacitances of the capacitors C11 and C12, and the residual charge can be neglected.

Steady pattern noise caused by variations in amplifier characteristics is typical when the image signal is small. In this case, the residual charge is further decreased.

From the above reasons, a means for resetting the input terminals of the amplifiers A1 to An is omitted. However, in an application wherein the residual charge cannot be neglected, a reset means must be connected to the inputs of the amplifiers A.

When the sensor and reference signals S1' and E1' are respectively held by the S/H circuits 12A and 13A, the above-mentioned difference processing is performed to cause the differential amplifier 14A to produce the sensor signal S1 as the output signal Vout free from the drive noise component and the noise component N1. Similarly, the sensor outputs S1 to Sn are sequentially output.

When all sensor signals are output, the next

sensor signals corresponding to the incident light are stored in the sensors B. In the same manner as described above, sensor read access and refreshing are performed for the blanking period BLK. Charge accumulation of the sensors B and dot sequential operation of the sensor signals temporarily stored in the capacitors are simultaneously performed.

When the clamp circuit shown in Fig.19 is used in the difference processing circuit 1A, the capacitor C12 for charging the reference signal E1 and then the capacitor C11 for charging the sensor signal S1 must be discharged. This applies to the signal readout operations of the sensor signals S2 to Sn.

Fig.21 shows a schematic arrangement of an image pickup system using any one of the image pickup apparatuses of the embodiments as an image pickup device.

Referring to Fig.21, an image pickup device 601A comprises an image pickup apparatus of any one of the above embodiments. The gain or the like of the output signal Vout is controlled by a signal processing circuit 602A, and the resultant signal is output as a video signal.

Various pulses  $\phi$  for driving the image pickup device 601A are supplied from a driver 603A. The driver 603A is operated under the control of a control

1 unit 604A. The control unit 604A controls the gain or  
the like of the signal processing circuit 602A on the  
basis of the output from the image pickup device 601A  
and also controls an exposure control unit 605A to  
5 adjust an amount of light incident on the image  
pickup device 301A.

As described above, in the solid state image  
pickup apparatus according to the above embodiments,  
a difference between the selected sensor signal and  
10 the selected reference signal is calculated to  
obtain an output signal free from the noise com-  
ponents. Therefore, the variations in readout signal  
depending on the potential variations of the input/  
output characteristics of the selector can be correct-  
15 ed. The steady pattern noise caused by the variations  
in amplifier characteristics can be eliminated.

A photoelectric transducer element used in  
Figs. 16A to 21 will be described as a supplementary  
explanation of Figs. 15C to 15E.

20 Fig. 22A is a schematic sectional view of a  
photoelectric transducer cell described in Japanese  
Patent Laid-Open Gazettes No. 12759/1985 to 12765/1985,  
and Fig. 22B is an equivalent circuit diagram of the  
cell.

25 Referring to Figs. 22A and 22B, photo-  
electric transducer cells are formed on an  $n^+$ -type  
silicon substrate 701A, and each photoelectric

1 transducer cell is electrically insulated from  
adjacent photoelectric transducer cells by an element  
isolation region 702A made of  $\text{SiO}_2$ ,  $\text{SiH}_3\text{N}_4$ , or  
polysilicon.

5 Each photoelectric transducer cell has the  
following structure.

A p-type region 704A doped with a p-type  
impurity is formed on an  $n^-$ -type region 703A formed by  
an epitaxial technique and having a low impurity  
10 concentration. An  $n^+$ -type region 705A is formed in  
the p-type region 704A by impurity diffusion or ion  
implantation. The p-type region 704A and the  $n^+$ -type  
region 705A respectively serve as the base and emitter  
of a bipolar transistor.

15 An oxide film 706A is formed on the  $n^-$ -type  
region 703A, and a capacitor electrode 707A having a  
predetermined area is formed on the oxide film 706A.  
The capacitor electrode 707A opposes the p-type region  
704A through the oxide film 706A and controls a  
20 potential of the p-type region 704A floating upon  
application of a pulse voltage to the capacitor  
electrode 707A.

In addition, an emitter electrode 708A is  
connected to the  $n^+$ -type region 705A, an  $n^+$ -type  
25 region 711A having a high impurity concentration is  
formed on the lower surface of the substrate 701A,  
and a collector electrode 712A is formed to apply a

1 potential to the collector of the bipolar transistor.

2 The basic operation of the above arrangement  
3 will be described. Assume that the p-type region 704A  
4 serving as the base of the bipolar transistor is set  
5 at a negative potential. Light 713A is incident  
6 from the side of the p-type region 704A. Holes in the  
7 electron-hole pairs generated upon radiation are  
8 accumulated in the p-type region 714A and the potential  
9 at the p-type region 714A is increased by the  
10 accumulated holes in the positive direction (charge  
11 accumulation).

12 Subsequently, a positive read voltage is  
13 applied to the capacitor electrode 707A, and a read  
14 signal corresponding to a change in base potential  
15 during charge accumulation is output from the floating  
16 emitter electrode 708A (read operation). It should  
17 be noted that the amount of accumulated charge is  
18 rarely reduced in the p-type region 704A serving as  
19 the base of the bipolar transistor, so that read access  
20 can be repeated.

21 In order to remove the holes from the p-type  
22 region 704A, the emitter electrode 708A is grounded,  
23 and a refresh pulse of a positive voltage is applied  
24 to the capacitor electrode 708A. Upon application of  
25 the refresh pulse, the p-type region 704A is forward-  
biased with respect to the  $n^+$ -type region 705A,  
thereby removing the holes. When the refresh pulse

falls, the p-type region 704A restores the initial state of the negative potential (refresh operation). Charge accumulation, read access, and refreshing are repeated as described above.

In order to restore the initial potential state of the p-type region 704A by refreshing, a refresh pulse having a sufficient pulse width is required. To the contrary, the refresh pulse width must be shortened to achieve high-speed operation. In this case, when the refresh pulse width is short, satisfactory refreshing cannot be performed. Unnecessary components such as a dark signal and drive noise are added to the after image.

Fig. 23 is a graph showing the relationship between a refresh pulse width  $t$  applied to the photoelectric transducer cell and the photoelectric transducer cell output.

Referring to Fig. 23, an output at  $t = 0$  is a read signal after charge accumulation and represents a read signal having a level corresponding to the intensity of the incident light.

The output level of such a photoelectric transducer is reduced by refreshing. However, the rate of change in output level and the level of the residual image upon refreshing vary depending on the intensity of the incident light.

When identical refreshing is performed, the

1 levels of the residual signals are not constant.  
When the intensity of the incident light is high, the  
level of the residual signal is high. In other words,  
the after image is typically formed.

5 The residual signal level of high-intensity  
incident light is higher than that of low-intensity  
incident light but is greatly lowered as compared  
with the initial read signal level. The ratio of the  
unnecessary components contained in the read signal  
10 is substantially low. On the contrary, the residual  
signal level of the low-intensity incident light is  
low. A decrease in the residual signal level is small  
as compared with the initial read signal level.  
Therefore, the ratio of the unnecessary components  
15 included in the read signal is high.

Even in the photoelectric transducer cell  
having the above characteristics, by subtracting the  
residual signal obtain upon refreshing from the  
initial read signal, the above-mentioned specific  
20 after image components as well as the unnecessary  
components such as a dark signal and drive noise can  
be simultaneously removed.

A second embodiment of the present invention  
will be described below.

25 Fig. 24 is a circuit diagram for explaining  
the basic arrangement of an image pickup element  
according to the second embodiment of the present



invention.

Referring to Fig. 24, an emitter electrode 708A of a photoelectric transducer cell S is connected to a vertical line VL and is grounded through a transistor Qr. The vertical line VL is connected to storage capacitors Ct1 and Ct2 through corresponding transistors Qt1 and Qt2. The capacitors Ct1 and Ct2 are connected to output lines 721A and 722A through transistors Qs1 and Qs2, respectively. The output lines 721A and 722A are connected to the input terminals of a differential amplifier 721A, respectively.

A pulse  $\phi$  from a scanning circuit SH is applied to the gate electrodes of the transistors Qs1 and Qs2. Pulses  $\phi t1$  and  $\phi t2$  are applied to the gate electrodes of the transistors Qt1 and Qt2, respectively. A pulse  $\phi rh$  is applied to the gate electrode of the transistor Qr. A read or refresh pulse  $\phi r$  is applied to a capacitor electrode 707A of the photoelectric transducer cell S.

The operation of the above arrangement will be described below.

Fig. 25 is a timing chart for explaining the operation of the circuit shown in Fig. 24.

The transistors Qt1, Qt2, and Qr are turned on in response to the pulses  $\phi t1$ ,  $\phi t2$ , and  $\phi rh$ , respectively, to clear the capacitors Ct1 and Ct2 (time interval T1).

1 Subsequently, the pulse  $\phi_r$  is supplied to the  
capacitor electrode 707A while the transistor Q<sub>t1</sub> is  
kept on. The read signal from the photoelectric  
transducer cell S is stored in the capacitor C<sub>t1</sub> (time  
5 interval T<sub>2</sub>).

The transistor Q<sub>t1</sub> is turned off while the  
pulse  $\phi_r$  is kept applied to the capacitor electrode  
707A. The transistor Q<sub>r</sub> is turned on in response to  
the pulse  $\phi_{rh}$ . The photoelectric transducer cell S  
10 is refreshed in response to the pulse  $\phi_{rh}$  (time  
interval T<sub>3</sub>).

Upon completion of refreshing, the transistor  
Q<sub>t2</sub> is turned on in response to the pulse  $\phi_{t2}$  while  
the pulse  $\phi_r$  is kept applied to the capacitor  
15 electrode 707A. The residual signal of the photo-  
electric transducer cell S is stored in the capacitor  
C<sub>t2</sub> (time interval T<sub>4</sub>).

When the read and residual signals are stored  
in the capacitors C<sub>t1</sub> and C<sub>t2</sub>, respectively, the  
20 transistors Q<sub>s1</sub> and Q<sub>s2</sub> are turned on in response to  
the pulse  $\phi$ . The read and residual signals are input  
to the differential amplifier 723A through the corre-  
sponding output lines 721A and 722A. A signal V<sub>out</sub>  
proportional to the difference between the read and  
25 the residual signals is output from the differential  
amplifier 723A (time interval T<sub>5</sub>).

As described above, the signal V<sub>out</sub> is a

1 signal free from the after image component and the  
unnecessary components such as a dark signal and drive  
noise and accurately corresponds to the intensity of  
the incident light. In particular, unnecessary  
5 component removal on the low-intensity side is  
effective, and an S/N ratio can be greatly increased.

Fig. 26 is a circuit diagram of an image  
pickup system of this embodiment. The circuit in  
Fig. 26 has  $n$  circuits of Fig. 24.

10 Referring to Fig. 26, the emitter electrodes  
708A of photoelectric transducer cells  $S_1$  to  $S_n$  are  
respectively connected to vertical lines  $VL_1$  to  
 $VL_n$ . The same circuits as in Fig. 24 are connected  
to the vertical lines. The gate electrodes of the  
15 transistors  $Q_r$  are commonly connected, and the pulse  
 $\phi_{rh}$  is applied thereto. The gate electrodes of the  
transistors  $Q_{t1}$  and the gate electrodes of the tran-  
sistor  $Q_{t2}$  are also commonly connected, and the pulses  
 $\phi_{t1}$  and  $\phi_{t2}$  are supplied to the common gate  
20 electrodes, respectively.

The gate electrodes of the transistors  $Q_{s1}$   
and  $Q_{s2}$  corresponding to the photoelectric transducer  
cells  $S_1$  to  $S_n$  are connected to the parallel output  
terminals of the scanning circuit  $SH$  and receive the  
25 pulses  $\phi_1$  to  $\phi_n$ , respectively. The transistors  $Q_{s1}$   
are commonly connected to the output line 721A and  
the transistors  $Q_{s2}$  are commonly connected to the

output line 722A. These output lines are grounded through corresponding transistors 103A. A reset pulse  $\phi_{hrs}$  is supplied to the gate electrodes of the transistors 103A.

A mode of operation of the arrangement described above will be briefly described with reference to Fig. 27A.

Fig. 27 is a timing chart for explaining the operation of the above arrangement.

As already described above, the capacitors Ctl and Ct2 corresponding to each photoelectric transducer cell are cleared during the time interval T1. During the time interval T2, the read signal from each photoelectric transducer cell is stored in the corresponding capacitor Ctl. During the time interval T3, each photoelectric transducer cell is refreshed. During the time interval T4, the residual signal of each refreshed photoelectric transducer cell is stored in the corresponding capacitor Ct2.

After the read and residual signals of each photoelectric transducer cell are accumulated in the manner described above, the pulse  $\phi_1$  from the scanning circuit SH is supplied to the gate electrodes of the transistors Qs1 and Qs2. The read and residual signals stored in the capacitors Ctl and Ct2 of the photoelectric transducer cell S1 are read out and

appear on the output lines 721A and 722A. A difference between these signals is calculated by the differential amplifier 723A, thereby removing the unnecessary components and hence obtaining the output signal Vout.

When a signal is output from the photoelectric transducer cell S1, the transistor 103A is turned on in response to the pulse  $\phi_{hrs}$ , and the charges left on the output lines 721A and 722A are removed.

In the same manner as described above, the read and residual signals of the photoelectric transducer cells S2 to Sn are output from the capacitors Ctl and Ct2 and appear on the output lines 721A and 722A and are subjected to subtractions by the differential amplifier 723A, thereby sequentially outputting signals Vout.

Fig. 27B shows another mode of operation of the above arrangement.

During a time interval  $T_s$ , the base electrodes of the cells S are reverse-biased to perform charge accumulation. Upon completion of charge accumulation, unnecessary charges on the vertical transfer line VL and the storage capacitor Ctl are removed before the photoelectric transducer signals are transferred to the storage capacitor Ctl within a time interval  $T_{vc}$ .

Refreshing is performed again during a time

interval  $T_{c1}$ , and drive noise is transferred to the storage capacitor  $C_{t2}$  during a time interval  $T_{t2}$ . Thereafter, the cell  $S$  is refreshed during a time interval  $T_{c2}$ , and the next charge accumulation cycle is initiated. The photoelectric transducer signal and drive noise which are stored in the storage capacitors  $C_{t1}$  and  $C_{t2}$  are output onto horizontal signal lines 721A and 722A, respectively.

In the above embodiment, the sensor shown in Figs. 22A and 22B is exemplified. However, the present invention is not limited to any specific scheme of the photosensor.

The present invention can be applied to a color image pickup apparatus of a scheme for processing a plurality of horizontal line signals.

Fig. 28 is a circuit diagram of a third embodiment of the present invention, and Fig. 29 is a detailed circuit diagram of a readout circuit  $R_i$  in this embodiment. This embodiment exemplifies a scheme for processing a signal of two horizontal lines. This can apply to any scheme for processing a signal of three or more horizontal lines.

Referring to Fig. 28, photosensors  $S$  are arranged in an  $m \times n$  area. Mosaic R, G, and B filters are arranged on the sensor surface.

Column photosensor outputs are respectively output to the readout circuits  $R_1$  to  $R_n$  through

vertical lines VL1 to VLn.

Referring to Fig. 29, in any readout circuit Ri ( $i = 1, 2, \dots, n$ ), the vertical lines VL<sub>i</sub> are connected to storage capacitors Ctl to Ct4 through transistors Qt1 to Qt4, and the capacitors Ctl to Ct4 are connected to output lines 801A to 804A through transistors Qs1 to Qs4, respectively. Since the scheme for processing a signal of two horizontal lines is used, two capacitors for storing the read signals and other two capacitors for storing residual signals are formed.

The gate electrodes of the transistors Qt1 to Qt4 are commonly connected through corresponding readout circuits R1 to R4. Pulses  $\phi_1$  to  $\phi_4$  are supplied to the gate circuits of the transistors Qt1 to Qt4.

A pulse  $\phi_1$  from a horizontal scanning circuit SH is supplied to the transistors Qs1 to Qs4 of the readout circuit R1. The transistors Qs1 to Qs4 are simultaneously turned on/off.

The output lines 801A and 802A are connected to the input terminals of a differential amplifier 805A, and the output lines 803A and 804A are connected to the input terminals of a differential amplifier 806. Signals OUT1 and OUT2 are output from the differential amplifiers 805A and 806A, respectively.

Two lines per field are selected by a vertical

scanning circuit 807A and an interlace circuit 808A. Pairs of two horizontal scanning lines in units of fields are selected in response to pulses Vr1 and Vr2.

The operation of the above circuit will be described with reference to Fig. 30.

Fig. 30 is a timing chart for explaining the operation of the above circuit.

Each photosensor read signal and its residual signal for two horizontal lines are read out during a horizontal blanking (HBLK) period and are stored in the storage capacitors in the readout circuits R1 to Rn. Transfer of one of the two horizontal lines is performed during a time interval Ta in response to the pulse Vr1. Transfer of the remaining horizontal line is performed during a time interval Tb in response to the pulse Vr2.

The transfer operations are substantially the same as those in Fig. 26. However, since transfer is performed during the HBLK period, the transfer time can be shortened as compared with a scheme for processing a signal of one horizontal line. Clearing of the residual signal storage capacitor and its charge accumulation are performed during substantially equal time intervals T3' and T3". Smear generated during signal transfer is proportional to the transfer time. In this sense, T2 (T2') and T3' (T3")



are shortened to suppress the smearing phenomenon.

The capacitors Ct1 and Ct2 are cleared within a time interval T1 in the time interval Ta. During a time interval T2, a pulse  $\phi r1$  is supplied to the first horizontal line in response to the pulse Vr1, and read signals of the photosensors on the first horizontal line are stored in the capacitors Ct1 in the readout circuits R1 to Rn. Subsequently, during a time interval T3', the photosensors of the first horizontal line are refreshed, and the residual signals upon completion of refreshing are stored in the capacitors Ct2.

During the next time interval Tb, the same transfer as in the first horizontal line is performed for the second horizontal line in response to the pulse  $\phi r2$  generated in response to the pulse Vr2. The read and residual signal of each photosensor for the second horizontal line are respectively stored in the capacitors Ct3 and Ct4.

When the read and residual signals of the first and second horizontal lines are stored in the capacitors Ct1 to Ct4 of the readout circuits R1 to Rn, the pulses  $\phi 1$  to  $\phi n$  from the horizontal scanning circuit SH are sequentially output to the readout circuits R1 to Rn, so that an R- and G-dot sequential signal OUT1 and a G- and B-dot sequential signal OUT2 which are free from the unnecessary

1 components are output from the differential amplifiers  
805A and 806A, respectively. It should be noted that  
the signal OUT1 is a G- and B-dot sequential signal  
and the signal OUT2 is an R- and G-dot sequential  
5 signal in the next field.

Fig. 31 is a schematic block diagram of an  
image pickup system using the solid state image  
pickup apparatus as an image pickup device.

An image pickup device 901A comprises an  
10 image pickup apparatus shown in Figs. 28 and 29.  
The output signals OUT1 and OUT2 from the image  
pickup device 901A are processed by an image process-  
ing circuit 903A through a sample/hold (S/H) circuit  
902A to produce a standard television signal such as  
15 an NTSC signal.

Pulses for driving the image pickup device 901A  
are supplied from a driver 904A. The driver 904A is  
controlled by a control unit 905A. The control unit  
905A also controls an exposure control unit 906A  
20 to determine an intensity of light incident on the  
image pickup device 901A.

According to the image pickup apparatus  
according to the third embodiment of the present, as  
described above, the residual signal is subtracted  
25 from the read signal of the photoelectric trans-  
ducer cell upon its refreshing to remove the unneces-  
sary components (e.g., a dark signal and drive noise)

1 of the photoelectric transducer element, thereby  
obtaining a video signal having a high S/N ratio. As  
a result, a low-cost, compact image pickup apparatus  
can be manufactured.

5 Fig. 32 is a schematic view of an area sensor  
for simultaneously reading out signals of two  
horizontal lines. This circuit includes switching  
transistors Tr11 to Tr22, bipolar transistors B-Tr10  
and B-Tr20, and capacitors Cox10 and Cox20. In this  
10 sensor, a photoelectric transducer signal and drive  
noise of the bipolar transistor B-Tr10 are respective-  
ly stored in the capacitors Ct1 and Ct2. A photo-  
electric transducer signal and drive noise of the  
bipolar transistor B-Tr20 are respectively stored in  
15 the capacitors Ct3 and Ct4. When these signals are  
to be read out, the photoelectric transducer signals  
are simultaneously and independently read out onto  
horizontal signal lines S2 and S3, and drive noise  
components are simultaneously output onto the  
20 horizontal signal line S1. Therefore, the drive noise  
components are output as a sum signal. R and G filters  
in an order of R, G, R, G, ... are formed on photo-  
electric transducer elements of the even-numbered  
rows, and G and B filters in an order of G, B, G, B,  
25 ... are arranged on photoelectric transducer elements  
of the odd-numbered rows.

Fig. 33 shows an image pickup system using

the area sensor shown in Fig. 32.

The image pickup system includes an inversion amplifier 60A, an adder 70A, a color separation circuit 80A, a color image signal processing system 90A, an area sensor 10'A, a driver 20'A, and a clock generator 30'A.

Photoelectric transducer signals S2 and S3 read out from the area sensor 10'A are input to the adder 70A and are averaged, thereby obtaining a signal in the form of  $R + 2G + B$ . The drive noise is inverted by the inversion amplifier 60A, and the inverted signal is input to the adder 70A. The adder 70A subtracts the drive noise from the photoelectric transducer signal, thereby producing a luminance signal Y consisting of only an information signal.

The color separation circuit 80A receives the photoelectric transducer signals S1 and S2 and separates them into chrominance signals R, G, and B. The resultant signals Y, R, G, and B are processed by the color image signal processing system 90A. The processing system 90A generates a standard television signal such as an NTSC signal.

In the above embodiment, the scheme for simultaneously reading out signals of two horizontal lines is used. However, the present invention is applicable to a scheme for simultaneously reading

out signals of three horizontal signals.

The storage capacitors can be omitted if the image pickup apparatus includes a shutter.

A subtracter for removing the drive noise may be connected to the output terminal within the apparatus.

In the above embodiment, the drive noise can be output independently of the photoelectric transducer signal, so that an external large-capacity memory need not be arranged.

In the horizontal line readout scheme, since the noise components can be added and its sum can be output, the number of horizontal signal lines can be reduced. Therefore, a multi horizontal line readout scheme can be easily achieved.

Fig. 34 shows still another embodiment of the present invention. In this embodiment, the differential amplifier 723A in Fig. 24 is replaced with a clamp circuit. The same reference numerals as in Figs. 15 to 33 denote the same parts in Fig. 34.

Fig. 35 is a timing chart for explaining the operation of the circuit shown in Fig. 34.

Cells S are reverse-biased to perform charge accumulation during a time interval  $T_s$ . Upon completion of charge accumulation, the unnecessary charges on the vertical transfer lines VL and in the storage capacitors Ctl are removed prior to transfer

of photoelectric transducer signals within a time interval  $T_{vc}$ . The photoelectric transducer signal is transferred to a corresponding storage capacitor  $C_{t1}$  during the time interval  $T_{t1}$ .

Refreshing is performed during a time interval  $T_{c1}$ , and drive noise is transferred to the storage capacitor  $C_{t2}$  during a time interval  $T_{t2}$ . Thereafter, the cells  $S$  are refreshed during a time interval of  $T_{c2}$ , and the next charge accumulation cycle is initiated. The photoelectric transducer signals and the drive noise are independently obtained. The signals stored in the storage capacitors  $C_{t1}$  and  $C_{t2}$  are dot-sequentially transferred on a single signal line  $S$  in response to drive pulses  $\phi_{s1}$  and  $\phi_{s2}$ . This operation occurs during time intervals  $TR_1$  and  $TR_2$ . A drive pulse  $\phi_{hrs}$  is used to reset the signal line to the reference potential. The signal obtained by the above-mentioned read operation represents a waveform of an output  $V_{out}$ . The drive noise and the photoelectric transducer signal are represented by  $W$  and  $S'$ , respectively.

The dot sequential signal  $S$  is input to a clamp circuit  $1A$ , and only the drive noise  $N$  is clamped in accordance with a drive pulse  $\phi_{s2}$ . As a result, the drive noise  $N$  is eliminated, and a true information signal indicated by a hatched portion in Fig. 35 can be obtained.

Fig. 36 is a schematic circuit diagram of an area sensor constituted by the photoelectric transducer elements shown in Fig. 34. Referring to Fig. 36, the area sensor includes a vertical shift register V-SR, a horizontal shift register H-SR, and  $S_{mn}$ , base accumulation type transistors arranged in an  $m \times n$  matrix. The operation of the area sensor is basically the same as that of the photoelectric transducer element shown in Fig. 34, except that the area sensor performs horizontal scanning and vertical scanning, and a detailed description thereof will be omitted. Clamping of the read signal, which is the characteristic feature of this embodiment shown in Fig. 36, will be described in detail.

A schematic waveform of the read signal is shown in Fig. 37. A signal  $S'$  appears on a read signal line  $S$ , and a pulse  $\phi s2$  is a drive pulse. Referring to Fig. 37, drive noise and the photoelectric signal of a cell  $S_{11}$  correspond to  $N_1$  and  $S_1$ , respectively. A cell  $S_{12}$  outputs signals  $N_2$  and  $S_2$ , a cell  $S_{13}$  outputs signals  $N_3$  and  $S_3$ , a cell  $S_{14}$  outputs signals  $N_4$  and  $S_4$ , .... The drive noise component of the dot sequential signal is clamped in response to the drive pulse  $\phi s2$ . As a result, the drive noise is removed, and only the true information signal can be obtained.

The above embodiment exemplifies a scheme

1 for reading out a signal of one horizontal line.  
However, this embodiment may be applied to a scheme  
for reading out a signal of one horizontal line in a  
time-divisional manner or a scheme for simultaneously  
5 reading signals of a plurality of horizontal lines,  
as shown in Fig. 28.

The base accumulation type transistor is  
exemplified as the photoelectric transducer element.  
However, a MOS or SIT image pickup device may be used  
10 as the photoelectric transducer element.

In the above embodiment, the drive noise and  
the photoelectric transducer signal are converted into  
a dot sequential signal, and clamping can be easily  
performed, thereby easily removing the drive noise.

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